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INTRODUCTION
TO A
General SYSTEM
OF
HYDROSTATICKS and HYDRAULICKS.

BOOK III.

CHAP. XX.

Of Hydraulicks, its Etymology, &c.



THE Etymology or Derivation of *Hydraulicks*, (tho' it is a Word rarely found in any of the Lexicons) is undoubtedly from ὕδωρ, or rather ὑδρὸς *aqua*, Water, or of, or belonging thereto; and αὐλὸς *Tibicen*, or *Tibia*, a Pipe: Since *Vitruvius*, *Lib. 10. chap. 12.* tells us, that the Ancients heretofore play'd all their Organs and other Instruments of Musick of that kind (which we now play with Wind) by Water.

“ THE Organs, (says he) were play'd by the Help of two Suckets, which were pull'd up or let down in the Body of the Pump, which Suckets press'd the Air with Violence into a Funnel revers'd in a Copper Coffer, half full of Water, and press'd the Water, and constrain'd it so as to ascend round about within the Coffer, which operated so, that its Weight in making it re-enter into the Funnel, push'd the Air into the Pipes, and made them play, producing the same Effects which the Bellows did.

THE learned *Harris*, in his *Lexicon Technicum*, says, that *Ozanam* is mistaken when he mixes and confounds *Hydrostaticks* and *Hydraulicks* one with another, since by the first is explain'd the natural

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Equilibrium or Motion of Water and other Fluids, and by the latter the Force of Mechanical Engines for the forcing it up to great Heights.

AND these Engines are of many and different Kinds; as First, those that are simple, as is the Siphon, Syringe, Antlia, or Single Pump, Screw Engine, and the like.

THE second are those that are compounded of the Pump and other Parts; as the Chain-Pump, Crankwork, Vibrating-Leaver, &c. the Wheels whereof are drove either by the Strength of Men, Horses, Water, Wind, and the like.

THE last is the Fire-Engine; an Invention of that great Use and Facility of working (especially in Coal-Mines) where it was at first chiefly design'd; so that we may, without Arrogance, challenge the whole World for such an Invention.

IT is requir'd in an Engine, that the Parts, whereof it is compos'd, be few, and those very simple and plain; for although in all other Machines, as the Jack, Clock, and Watchwork, as also in raising a great Weight, there is a Necessity of a great Number of Wheels and Pullies, either to retard its Motion, and to keep it long from going down, or in the other Case, to make the Ascent of heavy Bodies more easy and regular; to which must be join'd, a most powerful Force. Yet in Machines for raising Water, the Case is alter'd. And the Friction is so great in a great Number of Cog-Wheels, Runlets, &c. that the Machine goes heavy, and its Imperfection is discover'd by that shocking and Noise which it makes, whilst a good Machine goes easy and smooth, and almost as silent as a Clock or a Watch, as whoever has seen that in *Blenheim* Bridge, can testify,

THE Ancients, as *Vitruvius*, lib. 10. cap. 21. sets down, had several sorts of Engines for raising of Water.

THE first was the Tympan, of which there were two Sorts; one elevated a great deal of Water, but not very high, for it only mounted to the Axletree of the Tympan, which was a great Wheel made of Planks, which made two Bottoms divided into eight Parts from the Center to the Circumference, each Separation having an Opening half a Foot wide, near the Circumference, to draw the Water, which being elevated on the Axletree, ran through the Cavities which were hollowed in each Separation.

THE second Machine was a Wheel which elevated the Water as high as its Circumference, by the Help of several Boxes, which were fastened about it, and which pour'd out the Water into a Reeve, as the Wheel (having mounted) began to descend.

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THE third Machine was a Chain with Buckets, as the one mounted, the other descended, being drawn by the Axletree.

THE fourth Machine was the Vice or Screw of *Archimedes*, with which, it was said, he drain'd off the Floods of the *Nile*, though *Vitruvius* makes no mention of the Inventor. This Vice was made of a long Beam, or Piece of Wood, sixteen Times as long as its Diameter; about this Piece of Wood was put obliquely, a Hoop of Willow Wood, besmear'd with Pitch, and it was conducted by turning it round, by the Means of a Handle or Wheel, the Bottom of which was fix'd in the Water, and the Top on a Post set to the Height, to which a Man was to raise his Water; and of this Kind there are several now in Use. But of this more in its proper Place.

BUT besides this, the Ancients had Engines for drawing or raising, which they call'd by the general Name of *Budromia* (as may be seen in the Chapter, where the Axis in *Peritrochio* is treated of) and were no other than for the drawing of Water out of Wells by a Chain and Bucket: But as all Engines of this Kind are now reduc'd into a more mechanical Method, they are now rank'd under the general Head of *Hydraulicks*, as has been set down more at large in the Beginning of this Book.

OF this Kind there were Engines, Machines or Mills, call them which you will, chiefly made Use of then, for the grinding of Corn amongst the *Romans*, which, as *Vitruvius*, *Lib. 10. Chap. 10.* says, were mov'd by the Help of a great Wheel, which had many Wings, which we now call Pallats or Ladles, and forced by the Current.

THE Axletree of this great Wheel travers'd another which had Coggs, that made the Lanthorn or Trundle Head go round, and which being plac'd horizontally, was travers'd with a Beam of Iron, which entring through above into an Iron in the Form of a Wedge, helped to fasten the Beam into the Millstone, above which was the Mill-hopper, in form of a Funnel. And thus far *Vitruvius* sets down, as to Mills, &c. chiefly used in those Times, for grinding of Corn, and sometimes for raising of Water: But later Experience has produc'd a much greater Number of Inventions, for raising of Water by Chain-work, Crank-work, the vibrating Lever, Fire Engines, of which in their respective Order.

BUT before I finish this Introduction, tho' it is a little facetious, I can't but present my Reader with the following Account, as it was sent me by a Gentleman of Wit and Humour.

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I need not trouble my Reader with the Names of Persons, unless I have Particular Orders for so doing, but hope he will take the Letter just as he finds it, as it demonstrates the several Uses to which Water Engines may be apply'd.

March 18th, 1727.

S I R,
 “ **S**IR THOMAS laid his Commands upon me, to give you an
 “ Account of the Water-works by him design'd, which comes
 “ from a Spring a Mile from his Hall, with a natural Descent all
 “ the Way, at least above 60 Feet high, falling naturally into the
 “ several useful Offices following, *viz.*
 “ 1st, IT serves a very fine Marble, but unusual Beaufet to
 “ wash his Glasses, and which will hold above nine Bottles, at least
 “ half Way in Water to cool his Liquor.
 “ 2^{dly}, THE next serves to turn the Spitt in his Kitchen, by
 “ which, instead of a Jack (and much more useful, and less
 “ troublesome) he roasts all his Meat.
 “ 3^{dly}, ANOTHER large Cock in his Kitchen, which serves all
 “ common Uses in the same.
 “ 4^{thly}, A Cock that turns in a Tubb, to keep the Wort
 “ cool in the same, to condense the Spirits from a Bolt-head
 “ still.
 “ 5^{thly}, THE next is the Brewhouse, where it serves 4 Cop-
 “ pers, the first plac'd 20 Feet high, to keep Water hot all the Day
 “ for brewing, mashing, and scalding of Vessels, and which falls
 “ into the mashing Tubb, and from out of the mashing Tubb
 “ into the under Deck, from thence into another Copper to boil
 “ the Wort, and from thence into a large Cooler, naturally by
 “ Descents, without either pumping or leading.
 “ 6^{thly}, AND lastly, (at present) in his lower Kitchen it roasts
 “ his Meat (as in the upper Kitchen), churns his Butter, dresses the
 “ Flower for his Bread, washes his Cloaths, grinds his Malt. And
 “ now give me Leave to add a 7th, upon the Anvil not yet
 “ brought to Perfection, which will be necessary and very useful,
 “ being lately married to a fine young Lady, and which he is
 “ now contriving, will be to rock the Cradle.

AND with this I shall conclude what I have to say in this Introduction.

C H A P.



CHAP XXI.

Of the mechanick Sciences, and their Uses in Hydraulicks, &c.



ITHERTO we have treated in general concerning Air and Water, and the natural Effects they have in *Hydrostaticks* and *Hydraulicks*; but as the latter is principally founded on *Mechanicks*, in order to the raising of Water so much above its natural and common Level, to the Tops of high Hills and elevated Situations, it seems requisite that we take such a View of these Sciences, as may (with the greater Certainty and Facility) introduce the Reader into that which is the chief Purport of this part of my Design; I mean *Hydraulicks*.

Of the Leaver.

THE first I shall begin with, is *Vectis*, the Leaver, which, as the learned *Wallis* has it, has its Derivation à *Vehendo*, and that *Vector*, *Vectio*, *Vectura*, *Vectigal*, *Convexum*, *Vexum*, *Vexillum*, are a-kin to it; and that it is called Leaver à *Levando*, because of its Uses in lifting or heaving.

Now the Power of this Instrument (which is of great Use in *Hydraulicks*) is more or less, according to the Point by which it is suspended: For Example, let A B, *Fig. 1. Tab. seq.* be the Leaver, O the Burthen to be mov'd, B the Point where it is to raise its Weight, A the Place where the moving Force is apply'd, and V the Force it self, F the *Fulcrum* or Prop by which it is sustain'd, and C the Center of Motion.

It is plain, that if that Center or Point of Motion were plac'd more up towards V and A as at D, that the Weight O, which is plac'd at B, could not be rais'd with that Ease which now it is, no, not although there were four times the Weight apply'd at A. This is further demonstrated, by *Fig. 2.*

IT would be foreign to my Purpose, at least it would take up more Room than I can allow my self in the Compass of this Treatise, to go through all the Uses of this ancient, but plain Instrument; and for the farther Satisfaction of those that are very curious of my Readers, I refer them to that elaborate Treatise of Mechanicks wrote by the learned Dr. *Wallis*, cap. 6. p. 572, &c. where it is very exactly treated of.

THIS Leaver we have been thus epitomizing, is also not improperly call'd a Scale or Ballance, which is a rectilinear Beam, as A B, *vid. Fig. 3.* made of a firm homogeneous Matter, every where of an equal Thickness, so that if it rest with its middle Point C upon the Prop D, its Ends will keep an horizontal Position; for which Reason it may be consider'd, as a Line without Weight. And if at equal Distances in A and B, or nigh A and B, the equal Weight X and Z be suspended immediately, or within two Basins of equal Poise, they will keep the same Situation.

BUT if the Weight X were to be heavier than the Weight Z, or the Prop at C were to be mov'd more towards either X or Z, then would appear that famous but yet intelligible Theorem, and which is indeed the Corollary of all the Experiments that can be try'd in Mechanicks, *that equal Weights suspended at unequal Distances, nor unequal Weights plac'd at equal Distances, can't equiponderate.*

AND from thence may be demonstrated, wherein the comparative Habit of Weights, suspended from an unequal Radius of the Ballance, does consist; for if the Weights M N, *Fig. IV.* are reciprocally proportionable to the Parts of the Beam, that is, if the Radius A C be two, and B C three Parts in Length, and again the Weight suspended at the End of the long Radius be two, and M hanging at the shorter End be three Pounds, these Weights will necessarily equipoise each other, as Experience sheweth; for M cannot descend, but that N must at the same time ascend; nor can the Radius C A in descending pass through two Parts of Space A C; but the longer C B will ascend through three Parts of Space to F. And since the two Pounds Weight N meets with the Resistance of a sixfold Impulse in passing through the triple Space B F, the three Pound Weight M moving in a double Space, will likewise suffer a sextuple Impulse. And thus it is plain, that it will be so in all other Cases, and therefore the Resistance of the ascending Weight will be equal to the Impulses of the descending. Hence also it is manifest, that N cannot be lifted up by M, (nor M by N) for the same Reason; and consequently they will mutually keep one another at Rest in Equilibrio,

as is in *Fig. 3.* Which being thus demonstrated, it necessarily follows, *that equal Weights suspended at unequal Distances from the Middle of the Ballance, can't equiponderate, as before.* For in the present Case, if to the Weight N never so little Weight more be added, it will necessarily destroy the Equilibrium; how much more, then, will it be taken away, if N by a farther Addition, (*viz.* that of a whole Pound) be suppos'd to be made equal to the Weight M?

BUT if instead of the Weight N, some other moving Force, especially that of a Man's Hand, were apply'd, then this Ballance returns to its first Appellation; the *Vectis* or Leaver not any ways differing from the Ballance in any essential Property.

AND if the moving Force, being something strongly actuated, move downwards, and the Weight to be mov'd at the same time be lifted upwards, the Leaver is then call'd *Heterodromus*; but if one of its Extrems C, (*Fig. V.*) be placed upon the *Hypomochlion*, or Prop, and the other be apply'd to the moving Force B, the Weight to be moved being placed between them both in A; so that the moving Force B must move the same Way with the Weight A, which is to be rais'd, then this *Vectis* or Leaver is call'd *Homodromus*. In which the Proportion of the Distances from the *Hypomochlion* or Prop are still the same; *viz.* B C being to A C reciprocally as the Weight and Forces, *viz.* as A is to B. For if at one End of the *Hypomochlion* or Prop, there be placed the Radius C b equal to C B, it is plain from the Nature of the Ballance, that the Weight of one Pound in b, to which the Weight A of four Pounds may be suppos'd to be equal in poise (by what has been already said) may be sustain'd and kept up by the Force of one Pound apply'd in B, (there being no Weight at the same time in A) that is, in plain Terms, the Force of one Pound on B weighs as much as four Pounds in A.

AND if the Arms or Radii of the Leaver lie not in a strait Line, but incline one to another, so as to make an Angle, the reciprocal Proportion of the Weight and Radii will not then be the same, but then the Proportion of the Weights X and Z (*Fig. 6.*) is estimated by the Distances of the Line of Direction; that is, as if B C, in *Numb. 1.* and A C, in *Numb. 2.* were the Arms or Radii of a rectilinear *Vectis*, and after the same Manner, if to one of the Radii D C of the strait *Vectis* or Leaver, there be apply'd a Force drawing upwards or downwards obliquely, *Numb. 3.* and 4. then it will not be as D C is to B C, but as A C to B C. *viz.* the perpendicular Distances to the Lines of Direction: So will the Weight Z, which is the Weight to be poised, be to the Force that raiseth it in X, which is seldom observ'd in vulgar Books of Mechanics.

AFTER the same Manner also, may Cranes, with which is drawn the Water out of Wells, be reckoned as Leavers; for in letting down the Bucket E, *Fig. XI.* the Force drawing the Chain or Rope B E downwards, and the Weight it self of the empty Bucket, is apply'd to the longest Arm of the Leaver B C, whilst the Stone D, which is heavier than the Bucket, lies upon the shortest C A; so that the Force drawing down the Chain, is requir'd to be so much the less, to overcome the Excess of the Weight D above the Weight of the Bucket and Chain, by how much the greater the Proportion of the Arm or Radius B C is to the Arm C A; but in drawing up the Bucket, which is now suppos'd to be full of Water, the Force that lifts it up, is in part, the Weight of the Stone D, but is apply'd to the shortest Arm of the inverted Leaver A C: whence it is, that if at most the Stone D were equal in Weight to the full Bucket, yet it could not raise it up, till, on the other Hand, some other Force, *viz.* that of a Man, be apply'd to the Chain, which may be able to out-lift the remaining Part of the depressing Force or Weight; which Thing is elegantly enough demonstrated by *Aristotle, Problem 28.* but yet may be set into a clearer Light, if we reduce it into Number, by forming it into some Case.

As for Example, suppose the Weight of the empty Bucket and Chain together to be forty Pounds, and the Stone D an Hundred Pounds, the Arm B C as two Pounds, the Arm A C as one Pound; which being suppos'd, the Force of a little above thirty Pound will be sufficient to sink the Pail; and, on the contrary, let the full Bucket, with its Chain, weigh ninety Pounds; which being suppos'd, the Weight ninety Pounds will be to the Weight an Hundred and eighty Pounds, as one to two; and therefore the Stone D, which is an Hundred Pounds, won't be sufficient to sustain, much less to raise the Bucket; but the Force of a Man equivalent to above eighty Pounds, is required to draw the Chain up, or to the Weight D there must be added ten or twenty Pounds, or else the Distance from C to A must be enlarg'd, or the Proportion from B to C diminish'd. But the first is the most eligible; where, if you apply a Lead Weight of fifty Pounds at C, it will add more Force at that Distance, than the Stone of an Hundred Pounds at D; of which more hereafter.

Of the Axis in Peritrochio.

THE Axis in *Peritrochio*, is a Machine, or Mechanical Instrument, proper for lifting great Weights, as the *Vectis* or Leaver is of small; and all Writers of Mechanicks reduce them both to one and the same Laws. It is (as the learned Dr. *Wallis* defines it, *cap. 7. p. 605.* of his *Mechanicks*) compos'd of a Cylinder, which is call'd the Axis, and which is sustain'd at each End with a *Hypomochlion*, *Fulcrum*, or Prop, call it which you will; round which, is a *Tympanum*, Wheel, or Crane, and is call'd the *Peritrochium*; in the Ambit or Circumference of which, Holes being made on purpose, are fixt in the *Scytale*, serving as Handles; to which, if a Force is apply'd, the *Peritrochium*, with its Axis, will turn round, on which the Ropes being rowl'd, they elevate or lift up the Burthen.

I SHALL not copy or translate what that learned Gentleman before-nam'd, or others, have set down as to the Original of the several Members of which this and the other useful Instruments of this kind are made, because it would lead me too far out of my Way; but in order to illustrate it the better, will, for example, suppose the cylindrical Axis to be moveable horizontally, about the central Pins or Nails at A B, (*Fig. VIII.*) to which a Rope being fastened by one of its Extrems, and wound round the Cylinder or Axis, having a Weight hanging at the other End, it will raise it so much the faster, by how much the oftner the Cylinder is turn'd round; for the facilitating of which, either one Leaver D A is transversly inserted into it, which must be turn'd round with a Man's Hand, or any other impelling Force, from D to d, &c. and so rendered perpetual, and sometimes for Conveniency, two, at least, are put in, as *D A C* and *d A c*, are transversly thrust through it, whose Extremities *D d C* and *c*, may be successively turn'd round, and so used as one single Leaver, the *Hypomochlion*, *Fulcrum*, or Prop, being always at the Axis of the Cylinder, or at the Center A; the longer Arm *d a*, or *D A*; the shorter one *a e*, or *A C*, being the Semidiameter of the Cylinder, from whose Extremity C, or the Periphery which it describes, the Weight to be rais'd is continually supposed to hang; and when it is in this Force, it represents that Engine which is commonly call'd the Windlass.

The Peritrochium describ'd.

FOR a more particular Description of the Axis in *Peritrochio*, to which all these Engines belong, it is nothing but a Wheel or Arbor furnish'd with Handles, (by the *Latin* Writers of Mechanicks call'd *Scytalæ*) which are also called Logs or Leavers, as D *d e f g* L *h*, &c. *Fig. IX.* and apply'd to the moveable or turning Axis A B, not differing essentially from the Windlass, and consequently not from the Multiplied Leaver; for here, also, the *Hypomochlion*, or Prop, is the Center of the Cylinder A, or the Axis A B, the Weight being suspended at D K, which is the same thing as if it was suspended in E L.

As to the Proportion to be observed in the Axis in *Peritrochio*, the learned Dr. *Wallis*, in his *Mechanicks*, *cap. 7. Prop. 1.* says, *that as the Perimeter of the Axis, to which the Weight to be mov'd is fixt, is to the Perimeter or Circumference of the outer Orb to which the moving Force is apply'd, or as the Diameter or Semidiameter of one, is to the Diameter or Semidiameter of the other; so vice versâ, is the moving Force, to the Weight to be mov'd.* To speak more plainly, in the Example that lies before us, let A E be the Axis or Arm to which the Weight to be moved is fixt, which suppose one Foot diameter, then consequently the outward Axis or Arm A D is three Feet. Now if the Weight to be rais'd is three Hundred Pounds, the Strength that raises it at that Distance, be it either the Weight of a Man, or any other accidental Weight, must be an Hundred Pounds.

Of the Windbeam.

THE Windbeam is nothing else but an erect *Peritrochium*, only it has but one transverse Beam, which is made to take out and in at Pleasure, a Hole being made through the Cylinder for that Purpose; to the two Parts of this Beam D A D, may be apply'd the Force of several Men at once, (see *Fig. 10.*) and is a very well known Engine for raising Corn to the Tops of Houses, the taking of Timber out of the Water, and laying it on Wharfs, for raising of vast Stones to the Tops of high Buildings, &c. The Strength of this Instrument, as indeed is that of all the rest, is in Proportion to the Weight it is to raise or let down, the Length of the Arm or Radius A D, being also in a due (*i. e.* in a triple) Proportion to the Semidiameter of the Axis A B.

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THE Crane, or Tread-wheel, is another Sort of *Peritrochium*, or Wheel, of a large Cavity, in which a Man at L, *Fig. XI.* is endeavouring to climb upwards; the right Hand turns its Ambit round, and at the same time windeth up the Rope E F on a cylindrical Axis, which being more and more shortened, and brought over the Wheels F and G, by degrees lifts up the Weight H, which being raised to the desired Height, (to wit, to I) the whole Frame turns about the Center K, (both Ways, to the right Hand, or the left, as Occasion requires) for the Conveniency of changing the Weight. To estimate the Power or Force of this Engine, you are to erect L A perpendicular to the horizontal Semidiameter of the Wheel, making the Proportion thus; as A C is to C B, so is the Weight to be rais'd to the moving Force.

THE next sort of Axis in *Peritrochio* I shall mention, is a horizontal Wheel, *Fig. VII.* which was heretofore drove by the Walk of an Ox or some other Animal, which walks upon the Wheel, at least endeavours to go forwards; and by this its Endeavour or Striving, it drives the Wheel backwards, and sets the whole Engine to work, which forces up the Water from the Bottoms of the deepest Wells, to a great Height, through Tubes that are furnished with their Buckets; and of this kind also, are such horizontal Wheels as are drove by a running Stream, or the rising and falling of the Tide. And near unto it are those by which our reverend and ingenious Mr. *Holland* and others draw their Water out of the deepest Profundity, only the Horse goes in the Out-side of the Wheel, and the Wheel turns with the Horse. The moving Force to raise this Water, ought to be so much the greater, by how much the higher it is to be impell'd or forced up through the Tubes or Pipes from the Bottom of the Well above its Brink, which is sometimes as high as the uppermost Stories of Buildings. These are to be estimated also, in the same Proportion as the Line A C, *Fig. VII.* which reaches from the Foot of the Ox, &c. treading on the Wheel, to the Center of the Axis, hath to the Semidiameter of the Axis C B. And to this Place also, may be referr'd other small Engines, as Turnspits, and the like; and to this also may be referr'd, the outmost Wheels of Water-Wind-Mills, and all other Mills that are work'd by Horses, as before; which, with their cylindrical Axis's, are nothing but Windlasses or Cranes, accommodated to the moving of the rest of the inner Works, which being turn'd by Horses, or the Weight of Water falling upon them, or the Force of Water running swiftly under them, drive them round, and are by so much the more powerful, by how much greater the Semidiameter of the Wheel,

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Wheel, or Length of the Leaver is, in Proportion to the Semidiameter of the Axis. And all these kind of Engines are call'd by the general Name of *Budromia*.

Of Cogg-Wheels.

COGG-WHEELS, when accommodated to their Axis, are nothing else but Windlasses, and their Coggs the Leavers or Handles; to which is apply'd a Man's Hand, for the moving Force, (if there be no Water or other Help). The Proportions of Cogg-Wheels to raise, or, in other Words, to overcome the Resistance of Weight, is also as the Semidiameter of the Axis is to the Semidiameter of the Wheel; so that by the Help of the Cogg-Wheel A D C, *Fig. XIII*, whose Semidiameter A C is to the Semidiameter of the Axis A C, as four is to one. So that a Man whose Force is equivalent to an Hundred Pounds, turning the Wheel A by the Handle F, which Handle it self also adds some Force, but is here to be neglected, will be able to raise four Hundred Pounds. But if to this Wheel be added another indented one G, whose Semidiameter *a c* to the Semidiameter of the Axis (Allowance being made for Friction) is supposed to be as three to one. These, by tripling the former Force, will render them sufficient to sustain twelve Hundred Pounds; and so the Wheels being multiplied on, the same Man, or the same Strength of Water, or other Force, will be able to raise more and more Weight; of which Multiplication of Forces, which is, as it were, infinite, Specimens enough are to be seen in all Mill and Water-works.

Of the Force of Pullies in the lifting and moving vast Burdens and Weights.

As the Windlafs, or *Peritrochium*, and the like sort of Cylinders, turning upon their Axis, have been proved in the preceding Chapter to have the Nature and Force of the perpetual Leaver; so the Pulley, which is a Wheel, not only turning about its Axis, but made so, that at the same time it is drawn up by the Rope or Cord that goes round it, may very well be accounted, (according to learned *Dialect*) an *Homodromous*, Leaver, or *Vectis*, as will be very evident, to any one that will but consider it well; for if the Cord which is put over the Wheel A F C, be fastened at one End in D, and the other E, be drawn upwards by some moving Force, so that at the same time a Weight suspended from the Middle of the Wheel be kept in Equilibrio, it is apparent that the moving Force is apply'd in A by one of the Extrems of the Leaver A C, the other

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Extream resting upon the fixt Rope or Cord D C. And lastly, 'tis plain, that the Weight F will be suspended from the middle Point B, and consequently as A C, the Distance of the moving Force, is to B C, the Distance of the Weight from the same, *viz.* as one is to two; so reciprocally the Weight to be mov'd or sustain'd F, will be to the Force sustaining it in E, *viz.* as an Hundred Pounds is to fifty.

Now there are two Things, especially, to be taken notice of in relation to the Axis in *Peritrochio*, and the present Pulley; the first is, that the Center C is the *Hypomochlion*, the Weight to be rais'd hanging from its Periphery, or Circumference; on the contrary, here the Center C sustains the Weight, the *Hypomochlion* being in the Periphery of the Wheel, is in the second Place moveable, together with the Weight, by this Means procuring a Perpetuity of the Action in the *Vectis* A B C, quite after another Manner, with half the Force, which otherwise, without this Application, could not be done. Now if this Pulley be fixt from above, it will afford no Help towards the lifting the Weight; for if the Pulley A B D, *Fig. 6. No. 2.* be suppos'd to be fixt from above, being only moveable about the Center C, the moving Force at E must be equal to the Weight it self; because the *Hypomochlion* in this Case, is in the Middle at C, and consequently the moving Force and Weight is equidistant from it, as in the Ballance; which very Thing happens in the Windlass, if the Weight A E to be kept or rais'd up, be hanged, not from the Extremity of the Axis B, *Fig. VII.* which is a much lesser Distance, but from the Extremity of the Wheel at the Distance A d, which is equal to the other A D.

Now, again, in relation to the Pulley G, *Fig. XV.* in its Combination with the lower one A, it is to be noted, that the lower one only has the Ratio of a mechanical Power, by whose Mediation it is, that a single Force will be able to sustain a double Weight by the aforesaid Ratio; but the upper Wheel is of little Use, only by its Volubility and Position, it facilitates the drawing of the Rope; for since the Nail D, which is supposed to be drove hard into a Wall, and by whose Help the Part of the Rope D C sustains or holds up one half of the Weight; just as if a Man held it up with his Hand, the moving or sustaining Force E G A, must of Necessity bear up the other Half.

THE last Example I shall produce under these Heads, is an Example of accelerated Motion from the Combination of three or four Pullies, the Invention of the ingenious *P. Bettinus*; by the Help of which, a Bucket, *Fig. XV.* may be brought to the Top of a Well

in half the Time which the common way requires in doing it. If the Rope or Chain $E T$, to which the moving Force is apply'd, be not immediately fastened to the Pail or Bucket, but to the Pulley $B A$, which, by the Assistance of the Rope $D B A G$, fastened a little above the Well at D , sustains the Bucket so that the Water may easily enter into it, and be drawn up by it; for while the Center of the Pulley C is raised up to c , 'tis very evident, that the Bucket G must at the same time be raised through double that Space to g , because, since the Space $E c$ by this Hypothesis is equal to the Rope $A G$, and $A B$, the Pulley doth so much shorten the Rope in its Ascent, its other Part $D B A$ being at the same time so much lengthened; it will necessarily follow, that in the Position of the Pulley $a c b$, the Rope $A G$ will be quite wound up, and that the Bucket G will be drawn up close to it: But here it is equally manifest, that the Strength or Force at E must be doubled; for the Pin or Nail D will always resist the drawing Force, as much as the Weight of the Bucket is, which is suspended by it, which therefore does, as it were, draw it downwards with an equal Weight. Nor will it be difficult from the foregoing Author, to understand after what Manner (the intermediate Pullies being thus multiplied) a given Weight may be raised to any given Height in a given Time: But at present this shall suffice.

Dr. Wallis's Account of Cogg and Complicated Wheels.

To finish what I have to offer in this preliminary Account of Machines, I shall add *Prop. 3. cap. 7.* of the learned Doctor's Mechanics, whom we have Occasion so often to mention, as it will put the Principles of Mechanical Hydraulicks into the properest Light of any yet produc'd.

LET the Center or Axis of Motion be C , the Tympan or Wheel $C A$, which being dash'd upon with the Current of a River at A , turns the Wheel round; and let there be to the same Axis of Motion C , a lesser cogg'd or tooth'd Wheel $C B$, which being joined with the former, are mov'd jointly together, as if it were about one common Axletree; and let $C B$ be to $C A$ as a is to b , or as one to three. The Force then in A , according to *Prop. 1.* of this Chapter, will be, therefore, to B , as b is to a , or as three to one; and therefore one Ounce in A will equipoise three Ounces in B .

MOREOVER, with the Center or Axis of Motion D , let there be another Wheel $D B$, so dentated or tooth'd, and so fitted, that its Teeth may agree with the Teeth of the Wheel $C B$, and so wrought into them, that by their Help the Wheel $D B$ may be turn'd about its

its Center or Axis D, and let them so fit, that the Number of Teeth of the Wheel D B be in the same Ratio to the Number of the Teeth in the Wheel C B, that is, the Ambit or Circumference of one, be in Proportion to the Ambit or Circumference of the other; and the Radius of one, to the Radius of the other; and let there be about the same moving Axletree D, a lesser Orbit or Wheel D E, which may move jointly about with D B, which shall be as a Windlass whereon the Rope shall be wound, and let the Radius D B be to D E, as c is to b , suppose as four to one, the Force therefore in B, will be equal to that in E, in Proportion as c to b , or as four to one. And therefore a Quarter of a Pound in B, will have the same Force as a Pound in E. And, as is just now shewn, one Ounce in A drives four in B; and therefore the Force of one Ounce in A, will sustain the Weight of a Pound in P, and the same Force will move or raise it, being never so little encreas'd.

BUT if that Weight does not depend directly from E to P, but remains on an oblique Plane T O in π , that Weight that is in π , will be to that in P, and will ponderate in the same Ratio as F I, (a Perpendicular of equal Height) will with T O, suppose as c to d , or as three to four. Therefore when the Force in A will draw or drive twelve in P, it will draw sixteen in π .

AND from this Form of all Kinds of Machines, (says this learned Author in his Scholium on this Proposition) it is, that a Judgment may be made how all Sorts of Clockwork and other Instruments of this kind, that are compos'd of dentated or (in plain Words) Cogg Wheels, are made, especially that Clock which *Pappus* describes out of *Hero Alexandrinus*, lib. 8. pro. 10. of his Collection.

AND from this it is, amongst many other Observations for common Use, that which *Aristotle* touches upon in the ninth Question of his Mechanicks, and which I have elsewhere hinted at, that large Wheels, Cylinders, Tympan, Spheres, &c. move with more Ease than smaller ones, which we often see happens in Chariot or Coach Wheels, in Spheres and Cylinders that are used on the Ground, in the Pullies or Wheels of the Windlafs, and the like.

CERTAINLY so it is in all Water Engines, where, if they be not too wide, less Water and less Weight will do than is requir'd to drive lower Wheels, and such Wheels will perform their Office much more regular and better, as all that have been conversant in the Coal-works of *Northumberland*, *Durham*, and other Places, can testify; but of that, more in its proper Place.

AND here, by the Way, I cannot but observe, that wherever your Head can't be made high, and you have not a great Strength of Wa-

ter, why this very multiplied Wheel may not supply that Defect for if by this little Combination of mechanical Powers, there can be three Times the Weight rais'd or forc'd as can be in a simple Engine ; suppose the Diameter of the first Wheel, what additional Strength may not be added by the other, so as by a little Water to force it up very high in tuberous Pipes ? But this only *en passant*.

To conclude this Account of Mechanicks, and the Necessity there is for every one that would inform himself well concerning Machines ; I have inserted what precedes and follows in this Account, as necessary to be known concerning Engines and Mill-Wheels in general. What has hitherto been set down, having chiefly had relation to the Proportion which the Perimeter of the Axis of the Wheel has to the Perimeter of the extream Orb to which any Force is join'd, or that the Semidiameter of the one has to the Semidiameter of the other, for their better Force in moving great Weights, as also, of the Power of Multiplying Wheels to that Purpose ; and before I quit this Doctrine of the Rowl or Wheel in the Axis in *Peritrochio*, it may not be improper to subjoin some Speculations concerning these rotund Machines or Instruments, that our Calculations on this Head may be the more intelligible, and better understood.

THE general Observation, before-mention'd, and which *Aristotle* in the ninth Question of his Mechanicks touches upon ; *that large Wheels, Cylinders, and Spheres, move with more Ease than small ones*, is here more particularly handled, and as there will be Occasion to limit this extensive Position, and to produce it in the best Light we can, let us bring it to its first Principle, and suppose that a Cylinder, such as *Aristotle* calls the Scytalis, or Rowler, that is us'd in Gardens, or for the smoothing of any Piece of rough Ground ; such as is in *Fig. 1. Tab. Seq.*

IF the Weight and Length of the Cylinder be equal, though the Diameter be more in the one than in the other, it is plain, from every Day's Experience, that you may rowl the larger with more Ease than you do the lesser ; because, in the first Place, the Center of the large Cylinder is higher from the Plane of the Earth than the small one is, and consequently a Man or a Horse pulls at it with the greater Advantage, the *Vis Motrix* or Strain being nearly horizontal to his Hands. But this, I say, is when the two Cylinders are made of different Materials, the one of Wood, and the other of Stone or Lead, of equal Length, though of different Diameters. And this is agreeable to what the learned *Wallis*, *Prop. 1. cap. 7.* of his Mechanicks, sets down ; where, treating of the Axis in *Peritrochio*,
from

from which this Figure is taken, it is evident, that the Force of the Pulley is nearly horizontal, at most not above five Degrees from it; for if the Rope at P were fastened, in order to be wound up more towards B, the higher you go, the more Difficulty you would meet with in drawing the Burden N R S on.

AND this is farther agreeable to what the aforesaid learned Gentleman has set down in *Prop. 3. p. 627.* of the same *Mechanicks*; where he tells us, that if the Axis of a fore Wheel was as high as the Breast of a Horse, the Draught Line, to which the Force is apply'd, would be horizontal, and consequently the Motion and Thing to be moved direct, because they are level; but that a Coach or Cart must ascend and descend great Hills and Mountains, (*Vid. Fig. 2. T O P*) it is necessary that the fore Wheel be lower than the hind ones, (which is not so much us'd in *Holland* and other level Countries, as in *England*;) for that the Draught should be rather parallel to the Hypothense or Acclivity of the Hill, than to the Horizon; because the Draught of the one is much easier than the Draught of the other; but, generally speaking, the Harness being so much lower than the Breast of the Horse, he may be said not only to draw, but also to elevate or lift up the Weight which is behind him. But of this only *en passant*, it not being of any great Consequence in the Demonstration of what we are upon.

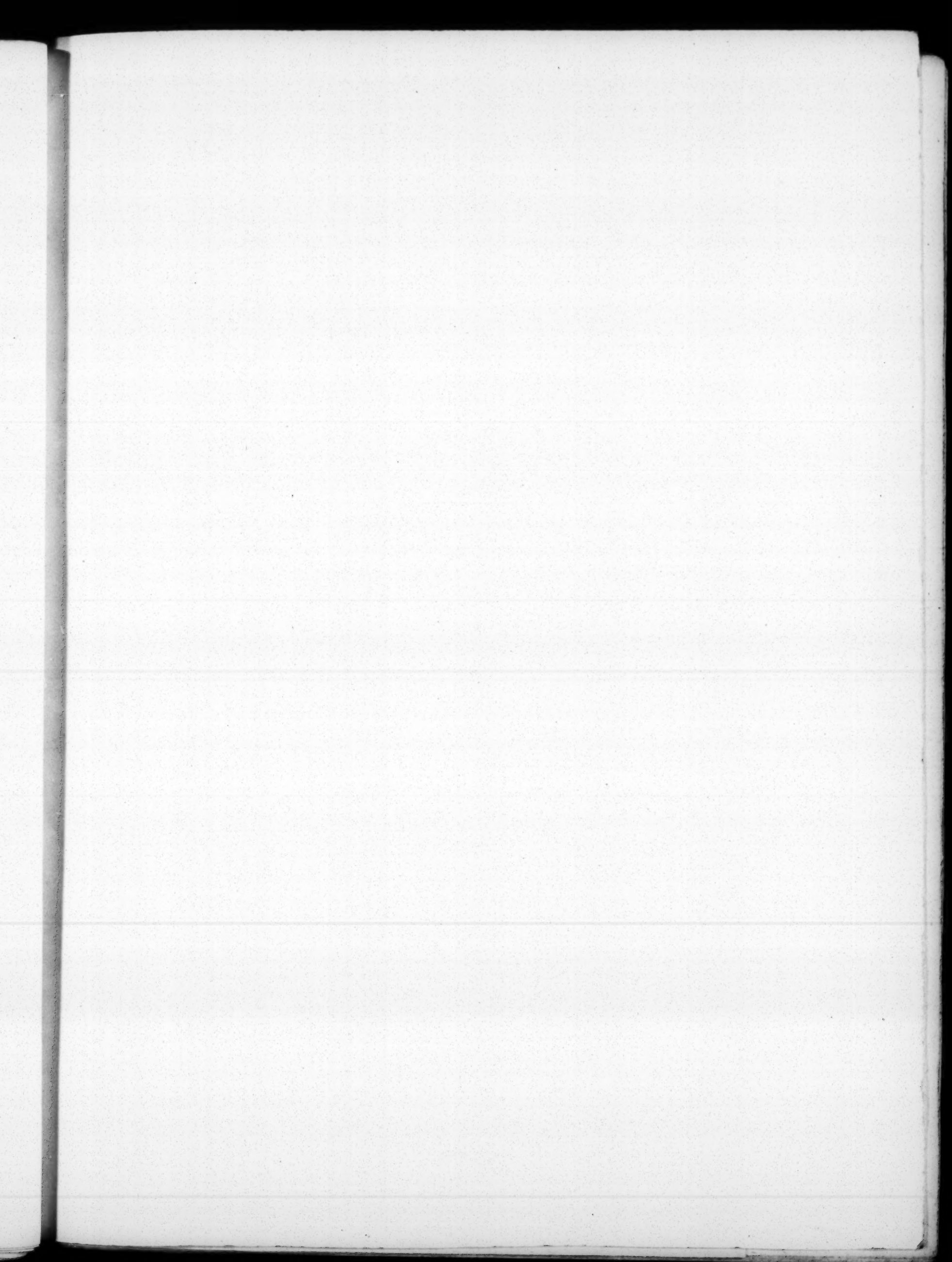
AGAIN, this Difficulty or Disproportion in Wheels, &c. whether for Water, or heavy Land Carriage, on low Wheels rather than high, is occasioned, as *Wallis* will have it, from the Friction of the Axis or Axletree in the Box; or, in other Words, the Adhesion of the Iron in the Axletree, to that which is in the Bore or Box, caused by the heavy Weight or Burthen that is laid upon it; and this is the Reason that *Aristotle* assigns, (in the 11th Question of his *Mechanicks*) why Rows that lie plain on the Ground, can carry greater Weights, (as in the moving of Barns, and other Edifices it is visible,) than Wheels will; to wit, from the Friction that is in the Axletree; for at the same time that the Weight lies upon the whole Cylinder, it there rests upon so small a Part as the Axletree only, which makes the Rotation stiff, but in the Row it is not so.

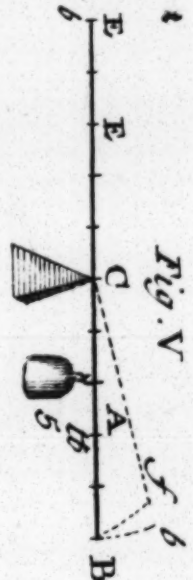
AND of this Opinion also, is our oft-quoted *Wallis, Prop. 3. cap. 7. p. 625.* of his *Mechanicks* before-mentioned; where, treating of the Axis in *Peritrochio*, he has these Words, *Positâ nempe eadem utrobique Axis magnitudine, quod frictione oritur impedimentum*, &c. of which a larger Account may be seen under the Head of Friction. And this is the Reason, says he, that the Axletrees and Wheels of Coaches and Waggon, when they are smaller, wear out, and re-

quire to be oftener repair'd, than those that are larger, from a Reason obvious to the most incurious Observer; to wit, from the Smallness of the Wheel, the Rotation of which is the oftener repeated, and consequently the Friction and Wear also, the Body resting thereupon being of an equal Weight, though not of an equal Diameter or Bulk; and for that, also, as the learned *Wallis* has it in his Account of the Difference of Wheels for Carriage, *Prop. 3. cap. 7. of his Mechanicis Cognatis*, that the incumbent Weight being greater on the lower Wheel than on the higher, it presses the harder upon it; as is demonstrated in his Treatise *de Vecte, cap. 6.* where the Leaver being placed on two Fulcrums or Props of unequal Heights, the Pressure is unequal also, pressing much more on the lower or hinder one, than it does on the fore or higher one. And the same ingenious Author adds, that it is not (as may be by some suppos'd) by the fore Wheels of a Coach or Cart's being lower than the hinder, that is an Advantage to it on account of the Weight pushing the same forwards; but, on the contrary, a Disadvantage, in crushing the fore Wheel, the Use of which, by that Lowness, is only designed for turning the shorter upon all Occasions, and not for the Discharge of the superincumbent Weight, or to facilitate its Passage forwards.

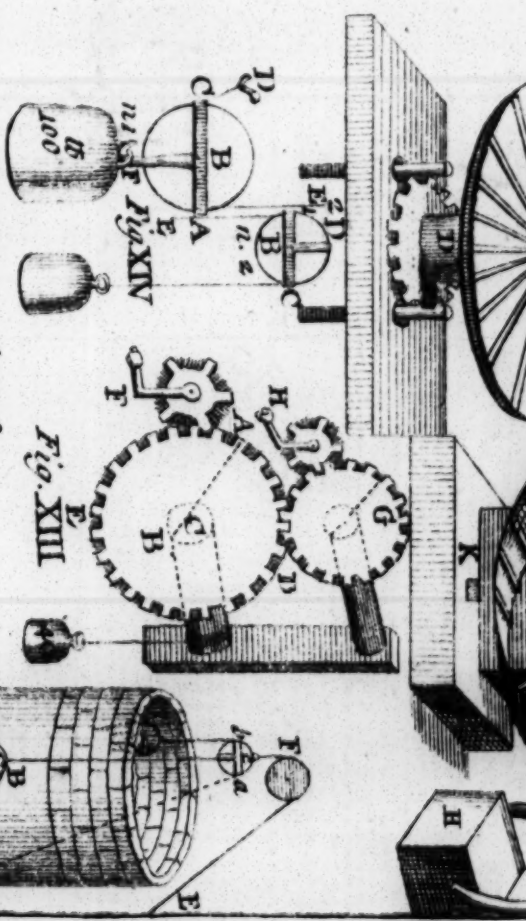
THIS, and much more, might be produc'd, to shew the Advantage there is in large Wheels more than is in small ones. But, on the other Hand, though this may happen in small Bodies, as Rowers, &c. yet if we consider the Resistance of Air, it is evident, that the greater Circumference a Wheel is of, so much the larger Portion of Air it has to contend with, and consequently the greater is the Friction or Resistance that must unavoidably stop, at least much hinder the Rotation of the Wheel, and must be the Occasion that large Wheels move with much more Difficulty on that Account, than small ones do; and this, amongst many other Reasons, seems to be one, why they have chang'd so many large Wheels as they have, in the Cloathing Mills about *Boking* and *Braintree* in *Essex*, for those that are of a less Diameter. But this is of no great Account.

AND, after all the Reasonings that may be on this Subject, (according to the Theorems and Experiments touching the *Vectis* or Leaver) certain it is, that a large Wheel will lift up a great deal more Water than a small one; because, it is plain, in the Case of the *Vectis* or Leaver, which is the Original of all Machines, the farther you place your *Vis Motrix*, or moving Force, from the Center, by so much the more is your Power encreas'd which is to raise any Body, whether a Fluid or a Solid; though it may true, that little
Wheels

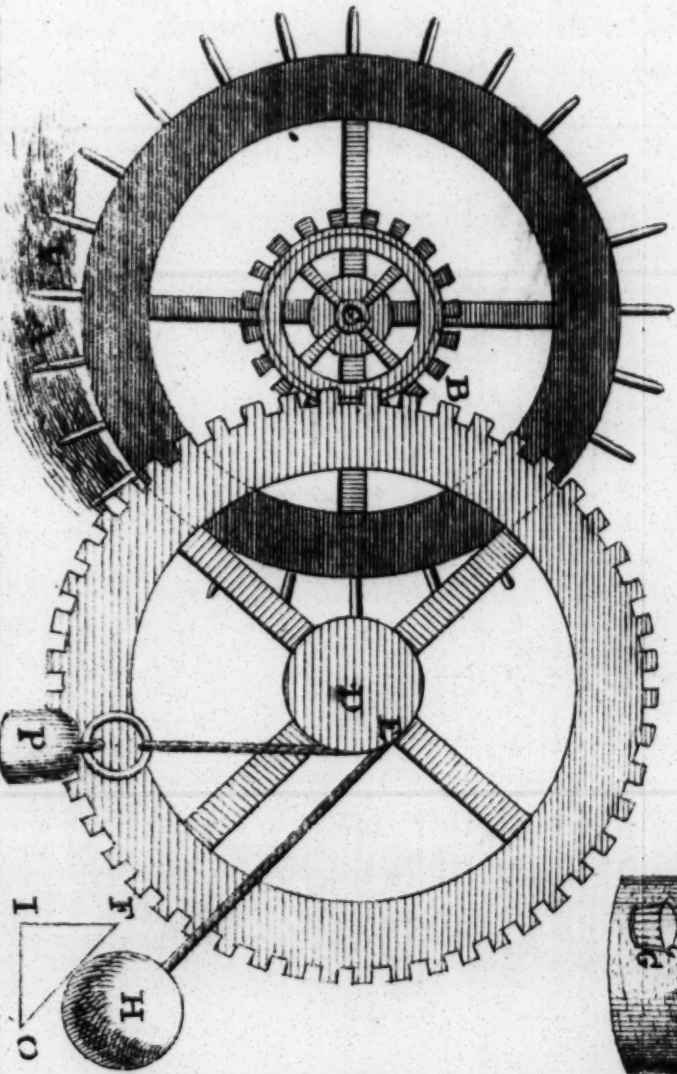
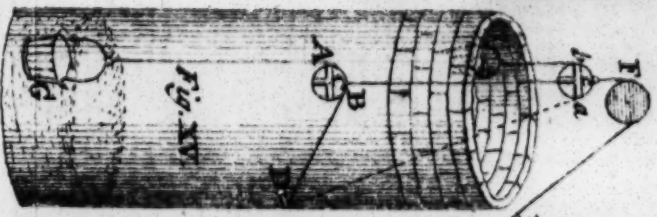




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The Orthography of
the Treble Wheel of Hero
Alexandrinus for Raising
Great Weights by water
from Wells



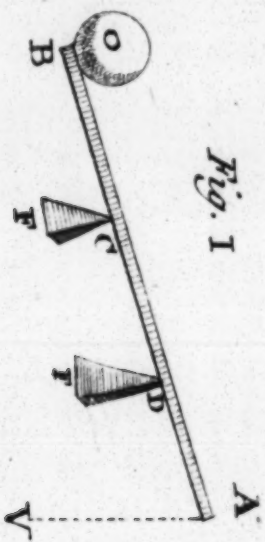


Fig. I



Fig. II



Fig. III

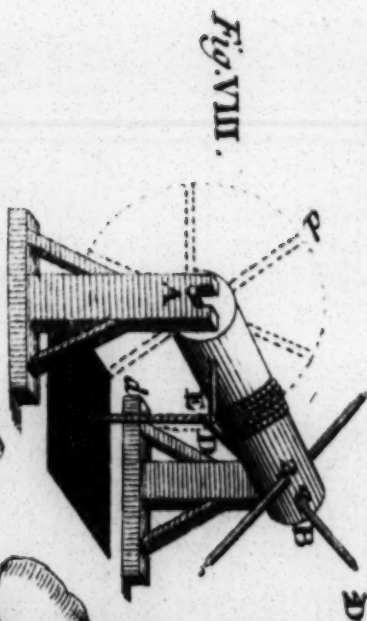


Fig. VII.

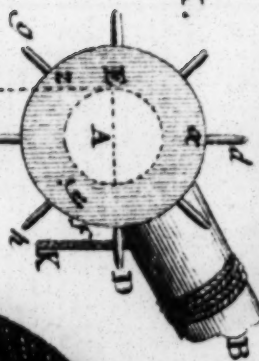


Fig. IX.

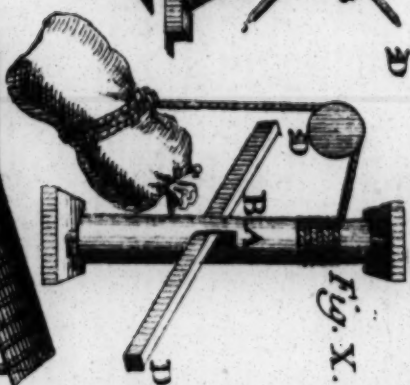


Fig. X.

Fig. XII

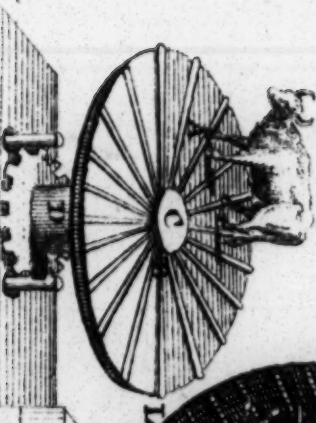
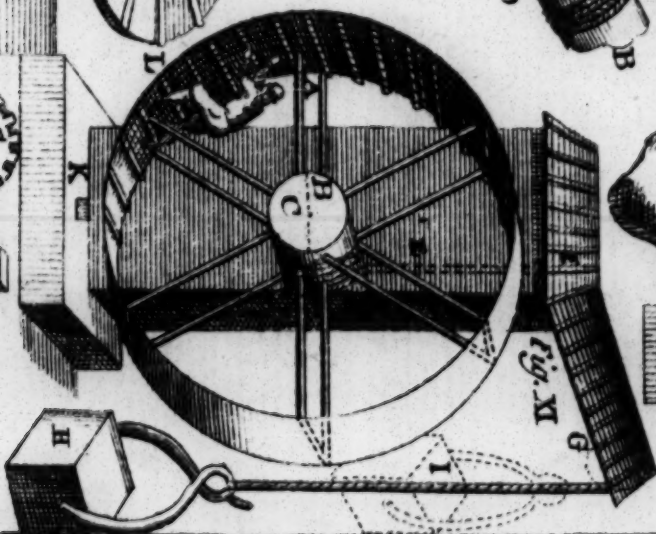
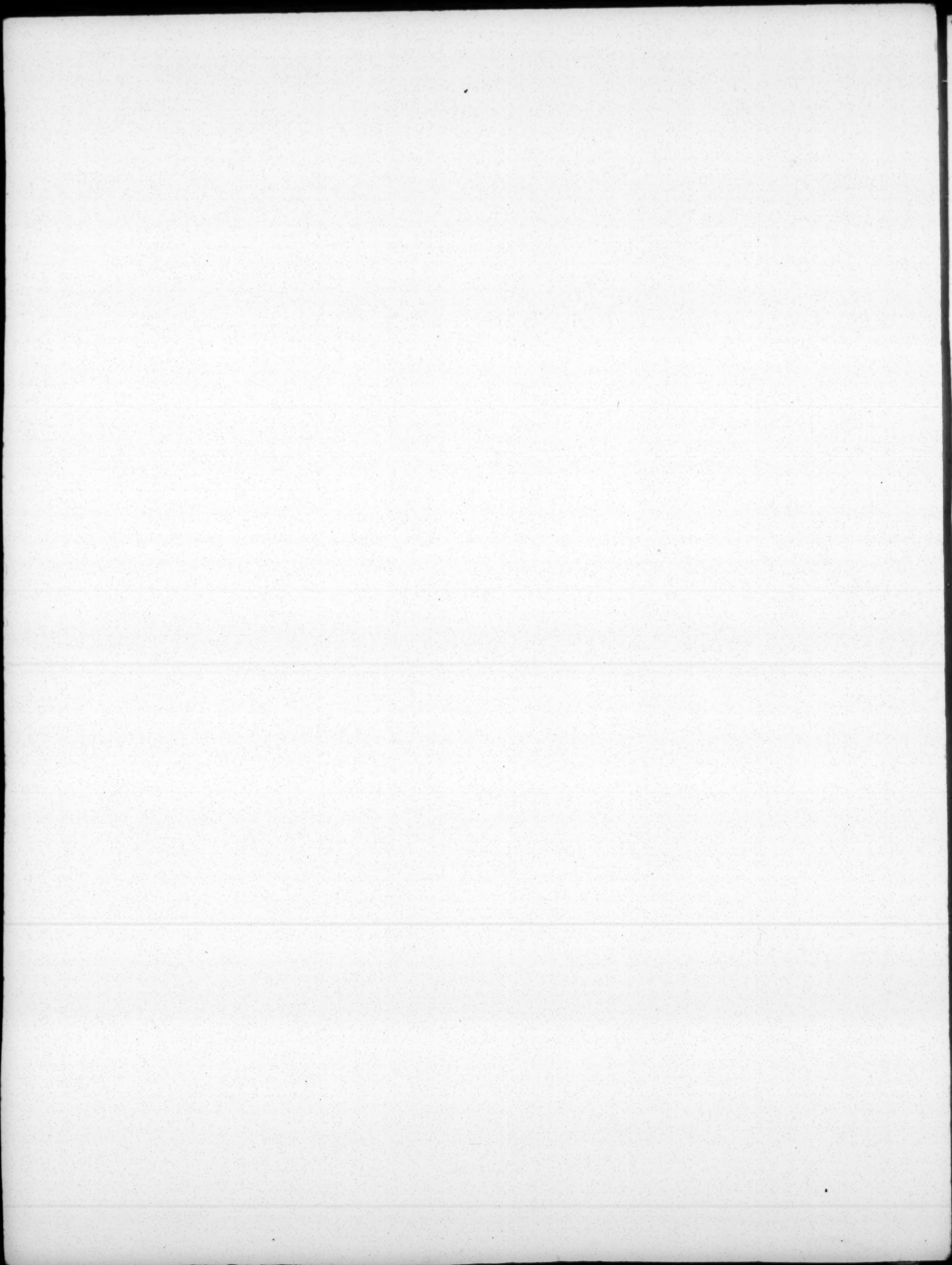


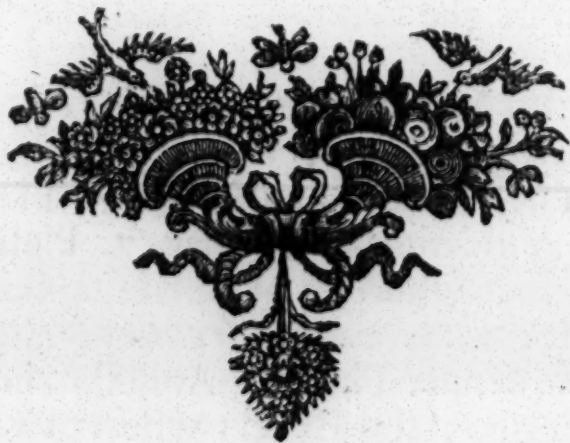
Fig. XI

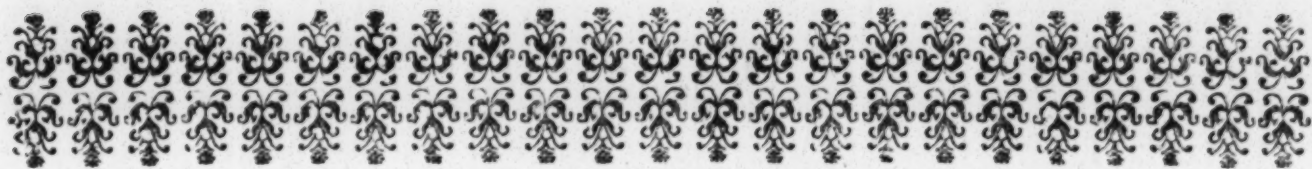




Wheels that are broad, may, by the impulsive Force of Water, effect the same Things as larger Wheels that are narrower.

AGAIN, in relation to Wheels, and their different Sizes and Positions, it is very certain, overshot ones are the best, especially where there is but little Water to drive them ; for, as has been elsewhere observed, in the Crane, or Tread-wheel. See one of the Figures in the foregoing Table, where a Man is endeavouring to climb up, if his Weight were at A, instead of *a*, and touch'd the Orbit of the tangent Line directly, rather than obliquely, the Wheel would move with the more Velocity, and consequently elevate the more Weight, by how much more the Water, or any impelling Force, falls into the Top of the Wheel at C, where, by undoubted Experiments, it has six Times the Force, and will consequently raise six Times the Weight, or, in other plainer Words, a sixth Part of the Water will drive an overshot Mill, as will drive an undershot one ; and the true Reason why there are not more overshot Wheels, is, that in most Places, especially in flattish Meadows, the Mill-Pond, or Head of Water, cannot be well rais'd above four or five Feet high, at most ; and as in those Places likewise, there are great Quantities of Water, (even to a Superfluity) there the great Waste of Water can't be discern'd, which it otherwise would, were it to depend on a small Rivulet or Spring. No overshot Wheel ought to be less than from six or seven Feet Diameter, to eight, ten, or twelve ; though as to Mines, especially at *Lumley-Castle* in the Bishoprick of *Durham*, there is one of twenty eight Feet. And this naturally leads me to what I have been all along aiming at.





C H A P. XXII.

Of the Siphon, and other Artificial Fountains and Jets of Water.

THE Siphon was undoubtedly the chief Instrument known in the first Ages of the World (besides the Draw-Well) for the raising of Water: And so great was the Veneration and Esteem they had for that Instrument, that the *Platonick* Philosophers (as I find it in *Bockler*) asserted, that the Soul should partake of the Joys of Heaven as thro' a Siphon. But this (says he) was rather parabolically, than really spoken. And *Theophrastus*, an eminent Physician of Antiquity, says, that the Marrow being thus drawn up thro' the Bones, causes, as it were, a kind of Corruption of that moist and vegetative Matter which is inherent in its Nature. From whence *Collumella*, a noted Philosopher and Gardener amongst the Ancients, asserts, that Vegetables draw their Nourishment thro' the Stalks and Stems of Shrubs, as it were through a Siphon, and that this Process is understood to be effected rather directly than obliquely; for when the Sun, by its long Heat, has drawn up a great deal of Moisture, lest there should remain any vacuate Space within the Cavity or Siphon of the Stem, the remaining Part of the Water is turn'd into Air.

To this Purpose also Mr. *Bradley*, in his *New Improvements in Planting and Gardening*, has a very pretty Conceit.

BUT not to detain my Reader any longer. The industrious *Ozanam*, in his *Cursus Mathematicus*, Chap. 7. Plate 13. gives an Account of several Engines whereby Water is to be rais'd, such as the Windmill, the Limace or Screw of *Archimedes*, and others, which I shall exhibit in their proper Places. And the first Machine I shall begin with, is this Siphon; the Effects whereof are so well describ'd by the learned *Gravesande*, Cap. 16. Book 2. of his *Elements of Natural Philosophy*.

Experiment 1. Figure 3. Tab. Seq.

LET (says he) one End *a* of the Curve Tube *a s b* be immerg'd into Water, whilst the other End *b* descends below the Surface of the Water. If by Sucking, or any other Way the Air be taken out of this Tube, the Water will run thro' *b*, and this Instrument we call a Siphon.

THIS Effect arises from the Pressure of the Air that drives on the Water, which is in the Siphon by its Weight on the Surface thereof in the Vessel. The Air also presses on the Water that goes out of the Orifice *b*, and sustains it. These Pressures are equal, and act contrariwise in the upper Part of the Siphon, without a Force equal to the Weight of the Atmosphere (as has been elsewhere declar'd) taking away the Weight of the Pillars of Water, which are sustain'd by this Pressure.

THE Pillar of Water in the Leg *s b* is longer than the opposite Pillar of Water; therefore the like Pressure of Air is more diminish'd on the Side *b s*, and the opposite Pressure overcoming it, the Water flows towards *b*.

Experim. 2. Fig. 4.

THE Siphon abovemention'd has this Inconveniency, that if it once ceaseth to work, the Water will not run again, unless the Air be drawn out of the Tube again afresh. But this may be corrected by making a Siphon, as in the Figure *a s b*, whose Legs are equal and turn'd up again; for if the Siphon be fill'd with Water, and one Leg be immers'd therein, so that the Surface of the Water may be above the Orifice, then the Water will run thro' the other Leg, for the Reason given in the Explication of the former Experiment; since the Legs are return'd upwards, the Siphon will not be empty'd when the running out of the Water ceases, and so the Siphon being once fill'd, is always ready to work its Effect; the Water running forwards and backwards thro' it, according as it is higher on the one Side than on the other.

Vide Fig. 5. Tab. Seq.] Upon the same Principles, as the foregoing Machines, is contriv'd the Siphon for raising Water into a Cistern. The Effect of which is seen by the help of a Machine made up of two hollow Glass Balls *H* and *I*, which are join'd together by the Tube *C D E*, the Ball *I* communicates with the Water to be rais'd up by the means of the Tube *A B*, which comes up almost to the
top

top of the Ball ; to the Ball H at the lower part, is join'd the Tube F G, as long as the whole Tube A B.

THE Ball H must be fill'd without Water thro' a Hole by a Funnel, and then the Hole must be shut up close. And in such Machines as are apply'd to use for raising Water out of a Reservoir that contains it, the Water is brought into the Vessel H, and the Communication between the Vessel and the Reservoir is shut up with a Cock.

Experiment 3.] Opening the Cock G, the Water will run out that Way, and the Water will ascend thro' the Tube A B, up into the Vessel I ; which being fill'd, the Water is suffer'd to run away to the Place where you would have it, and by repeating the Operation, the Elevation of the Water continues.

OPENING the Cock G, the Air presses against the Water going out of the Tube F G ; the Air also presses upon the Water in the Reservoir, and sustains that which is in the Tube A B. These Pressures are equal, and if you take from the Columns of Water which they sustain, you will have the Forces by which they act upon the Air contain'd in the upper part of the Vessels, and the Tube C D E, the Pillar F G, because there is superadded to it the Height of the Water in the Vessel H, does always overcome the Column in the Tube A B, as being longer ; therefore the Pressure at G is less diminish'd than the other, and so is overcome by it, and therefore the Water must rise in the Tube A B, and descend down F G.

Of the Limace or Screw-Engine.

THIS Engine was, as some say, first invented by *Archimedes* (though *Vitruvius*, who gives an Account of it, does not mention the Author) for the Benefit of the *Egyptians* when they were overflow'd by the River *Nilus*, and is amongst the Number of those that are mention'd in the beginning of this Account of ancient Engines.

THE *Hollanders* have long ago (as some Books, that I have seen of theirs of Fortification, intimate) us'd them in draining their morassy and fenny Ground ; from whence they have been brought into *England*, and us'd in the Fenns of *Lincolnshire*, *Cambridgeshire*, and other low Countries, especially in the clearing of their Dykes, and to make room for their Labourers to work. It is of admirable Use in drawing the Water out of Fish-Ponds, where there is little or no Current, in order to the taking out the Fish and cleansing the same. And in *Oxfordshire*, as is elsewhere intimated, they use them in watering their Meadows, where the Level or Course of their Rivers lie too low to float them by Nature.

Fig. 1. in the next Table but one, there is a *Cutt* of that Engine, the Description of which take as follows. In the first Place there is a Rafter 10, 12, 14, 16, 18 or 20 Foot long, as you have Occasion to elevate your Water, though the latter require Horses to work them, but the first may be wrought by Men. This Rafter or Piece of Wood may be also from 10, 12, 14, 16, 18 or 20 Inches Diameter, according to the Length, allowing an Inch in Diameter to a Foot in Length, and it must be made round, only about a Foot and a Half is to be square at Top, on which is fix'd a Trundle Wheel.

At each End of this Rafter or Wheel-tree is an Axis or Gudgeon of Iron as the Mill-wheel has, for the Engine to turn upon; then within three Quarters of the lower End there is a Regal or Groove, which must be made in the Wheel-tree half an Inch deep, to fix the Boards in, and carried spiral in the Manner of a Skrew (which, as *Vitruvius* mentions, should be made the Rectangle of *Pythagoras*) or like a winding Pair of Stairs, for so it will appear; next you must take deal Boards, they being the lightest, 18 Inches long; the one End of them is to be fix'd in the Groove, with Pitch and Taw, to prevent the Water getting in between, and then this seeming Stair-Case is to be cover'd over with Deal Boards, which are to be pitch'd or painted, and the Skrew or Stair-Case is also to be groov'd into those Boards, about half an Inch deep, and the Joints pitch'd as before, and after that cover'd with Iron Hoops, set at every two or three Foot assunder, which makes it appear like a long Cylinder or Barrel.

THOSE of the smallest Kind that are work'd by Men have only an Iron Handle, as a Grinding-stone has, but the largest that are wrought by Horses have a Wheel like the Cogg-wheel of a Horse-mill, only the Coggs stand downwards; and it is drawn by one, two, or three Horses, as there is Occasion, Planks being plac'd for them to go upon.

THE Bottom of this Engine is plac'd in the Water, the nether Gudgeon running in a Piece of Timber plac'd for that Purpose in the Water, the Engine lying sideways; the upper Gudgeon is likewise plac'd in the Engine very truly; so that the Cogg-wheel may turn about the Engine, and at the upper End of the Barrel of this Engine is generally plac'd a Trough to receive the Water, as it comes out of the Skrew, and to convey it away into some Ditch.

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THIS Engine, which takes Hold of the Water, as a Cork-Screw does a Cork, will throw up Water as fast as an overshot-Mill, whereby in a short Time an infinite Number of Water may be thrown up; and I remember when the Foundation of the stately Bridge of *Blenheim* was laid, we had some of them us'd with great Success; and they are also us'd in the new River Works about *Newbury Berkshire*, and said to be the Contrivance of a common Soldier, who brought the Invention out of *Flanders*.



C H A P. XXIII.

Of the Antlia or Pump; its Description, Uses and Kinds, &c.



THE Antlia or Pump was, as *Vitruvius* and *Hero Alexandrinus* informs us, the Invention of *Ctesibius* a Barber's Son of *Alexandria*; and therefore in Compliment to him for this, his so useful a Machine is by *Wallis* and others still call'd the *Ctesibian Pump*, though made different Ways.

Vitruvius, *Lib. 10. Cap. 2.* gives an Account of this Machine, which, as is elsewhere intimated, was first used for the playing of Organs, and other Instruments of Musick, of which *de Caus* the famous *French Engineer* has given us several Designs, which I shall exhibit in their proper Places: But this Pump, as describ'd by *Vitruvius*, does not appear to be the same that *Wallis* and others give us; this being effected by Pressure, and those that they describe by Suction, or rather the Pulsion of exterior Air gravitating upon the Water, when the Air is drawn out of the Tube by the Piston.

THE industrious *Ozanan*, *Book 3d. Page 178.* of his *Mechanicks*, has given a particular Account of these two Kinds of Pumps, and of the Manner by which they work their Effects; the first he calls a force Pump, which seems to be the same which was us'd by its first Inventor *Ctesibius* above-mention'd, for the playing of Musick.

THE

THE *Second* Kind of Pump he calls a *sucking Pump*, which is effected by the Pressure of the Air, after the Piston is rais'd, which sucks out the Air that is therein, and gives Liberty for the Water to ascend and fill that Place, contrary to the Motion of a Vacuum.

AND, *Lastly*, he calls such a Pump as raises Water, by pushing it upwards, a *lifting Pump*; but of this and the Effects, and different Manner of working of these Pumps, I shall write more in its proper Place, and with the learned *Gravesande*, &c.

MONSIEUR *Ozanan*, who is one of the first and chief amongst the Mathematicians, who in his *Curfus mathematicus*, Page 180. Fig. 143. has treated of Pump Works, in treating of Crank Work, observes that the Force of Rivers is commonly made Use of to play Engines of this Kind, when compounded into Crank or other Work, by Means of a Wheel, as A. Fig. 2. of the next Table but one, whose Floats, dipping in the Water, are push'd by the Force of the said Water, so as to cause the Wheel to turn, which turns the bended Piece of Iron or double Crank B C D, which bearing upon the fix'd Points E F, and turning upon them successively, comes nearer to, or goes farther off from the Holes I K of the two Barrels I L, K m, and so raises and sinks the Pistons, one after another, by Means of their Rods, B, G, C, H, which are fast'ned to the double Crank, B C D at the Points B C; so that the whole Force of the Engine, which, as hereafter will be more amply shewn, uniting together, drives up at Bottom, and obliges it to go up into one Pipe, which is common to both Pistons; the Motion and Ascent of Water thro' the ascending Pipe, (tho' not so uniform and regular as when there are three or more Pistons, as is often done in Leaver Work) nearly continual, and without Interruption, the two Cranks forcing alternately, and succeeding each other's Stroke.

THE Proportion for the Strength and Depth of such Cranks is according to the Strength of your Wheel, which depends on the Height and Cylindrical Weight of Water, that such an Engine is to force up, which is by so much the more, in as much as the Stroke or Force, and consequently the Weight of Water is double of what any single Engine or Pump sustains and forces.

AND with the learned *Gravesande*, to render the Effect of these common Pumps the more visible, let there be a little Pump made of Glass, in the following Manner, A B Fig. 3. *Tab. seq.* must be a *Cylinder* of Glass, about an Inch and a Half Diameter;

in the Bottom of it join a Tube of any Length, as *C D*; Let the upper Part of it be shut by a leaden Ball, so that the Water may not be able to ascend out of the Cylinder, but may easily rise in to it, by raising up the Ball which is here made use of instead of a Valve; the Piston is mov'd in the Cylinder *A B*, which, being surrounded with Leather, exactly fits its Cavity; there's a Hole likewise in the Piston, which is likewise stopt with a Ball of Lead, instead of a Valve, so that the Water may rise, but not descend through the Piston.

IN the next Place, you are to push down the Piston to the Bottom, and to pour Water into it, to hinder the Passage of the Air; if the End of the Tube *C D* be immers'd into Water, and the Piston be rais'd, the Water will ascend up into the Cylinder *A B*, from which it cannot descend; wherefore it comes up through the Piston, when it is push'd down; and if you rise the Piston again, the Cylinder is again fill'd with other Water, and the first Water is rais'd up into the Wooden Cylinder, which is join'd to the Glass one, from which it runs through the Tube *G*.

BUT since the Effect of all these Kinds of Machines depends upon the Pressure of the Atmosphere, the Water will not rise above 32, 33, or 34 Foot at most.

BUT to shew the Nature of this external Pressure of Air, and the Effect it has on artificial Fountains, the said ingenious Author has produc'd one from *Hero*, (*a*) the Construction and Effect of which take as follows.

LET *Fig. 4. Tab. seq.* be two equal Elliptical Vessels *A B*, and *C D*, exactly shut on all Sides, and made of any Sort of Metal.

IN each of them there is a Separation passing through the Center of the Ellipsis, which divides the whole Vessel into two equal Parts.

THE Separation *m n i* in the Vessel *D C*, is perpendicular to the Axis of the Ellipsis, the Separation *c f g b* of the other Vessel must be inclin'd to that Axis.

THERE is a Brim made about the upper Part of the Vessel *A C B*, to make a Basin.

FOUR Tubes are join'd to these Vessels, the *First*, *op* go through the Cavity *B* of the Vessel *A B*, without having any Communication with it, and descends almost to the Bottom of the Cavity *D*, and ascends to the upper Part of the Cavity *B*, but not quite so high as to touch the upper Plate of it. The *Third* *q r* reaches from the lower Part of the Cavity *B*, almost to

to the Bottom of the Cavity C; the *Fourth* X *n* is made fast to the upper Part of the Cavity C, and reaches almost to the upper Part of the Cavity A.

Lastly, THERE is a Tube *z y*, which going through the upper Plate, is solder'd to it, and reaches down so deep in the Cavity A, that its End *z* is but a little Way off the Bottom.

THERE are Cocks join'd to every one of these Cavities, or else they have other Holes that are shut up with Screws that have Leather on them; the chief Use of them is to let out the Water very clean from the Cavities, lest they should grow rusty when the Machine is not in Use.

To come to the Experiment of this artificial Fountain, pour in Water thro' the Tube *o p*, so as to fill the Cavity D; and if you continue to pour in Water, it will rise up through the Tube *s t*, and then descend through *q r* into the Cavity C, which is also fill'd, the Air ascending through X *n*, and going through *z y*.

TURN the Machine upside down, opening the Cocks of the Cavity C and D, the Water will descend into the Cavities B and A: Having again shut the Cocks, as also the Hole *y* of the Tube *z y*, set the Machine again the right Side upwards, and pour Water in again through the Tube *o p*, till the upper Surface of the Machine be cover'd with Water. Now, if the Hole *y* be opened, the Water will spout up to almost twice the Height of the Machine, and the Motion of the Water will continue till the Cavity A be emptied with its Water; the Height of the Spouting-water will continually diminish, and at last it will be double the Distance of the Vessels.

THE Effect of this Machine is to be attributed to the Compression of the Air in the Vessels; the Pressure of the Atmosphere at *o* and *y*, as also in the Vessels is equal, but their Pressures destroy one another, and therefore are not to be considered in the Examination of this Machine: When at last the Water is pour'd into the Tube *o p*, it is sustain'd in it by the Pressure of the Air contain'd in the Cavity D, and acting upon the Surface of the Water, which stands at a small Height in that Cavity; which Air therefore is compress'd by the Weight of the Water, whose Height is *p o*; we speak of the Pressure, by which the Pressure of the Atmosphere is overcome.

THE Air in the upper Part of the Cavity B, communicates with the Air abovemention'd, by the Tube *s t*, and is equally compress'd, and acts with the same Force, upon the Surface of the

the Water in that Cavity: This Pressure is to be added to the Pressure arising from the Height of the Water, in order to have the Force by which the Air is compress'd in the Cavity C, as also the upper Part of the Cavity A, by Reason of the Communication through the Tube X π ; the Pressure therefore upon the Surface of the Water in that Cavity A, is equal to a Pillar of Water, whose Height is double the Height of the whole Machine; and therefore it spouts up, as if it was press'd by such a whole Column; that is, to a Height not much wanting from the Height of that whole Column.

THIS Height is continually diminish'd, for the Columns of Water which compress the Air become shorter and shorter, because the Water ascends in the Cavities C and D; and its Height is diminish'd in the Cavity B, at the same Time that the Cavity is continually evacuated, and the Water ascends through a greater Space, before it comes to Y; therefore it is driven to a less Height than Y.

AND thus much of the Description and Theory of this useful Instrument: Let us now enquire what is proper to set down, as to its Uses, and the several Kinds of them.

MONSIEUR Ozanan informs us, That Sir Samuel Moreland was the first who brought this Pump to any Degree of Perfection with us; which I take from that *French* Author, having taken great Pains to find out what Sir Samuel has left on that Head to no Purpose: But as Ozanan tells us, it was at that Time an Invention which he valued very much; let me explain it in his own Words, and make Use of the same Drafts he has given it us in; NOR is the Profile of the Pump, (*vid. Fig. 10. Tab. seq.*) the Sucker which is at the Bottom of the Pump L N the Piston, which must be a Cylinder of Brass, exactly turn'd in the Lathe, made to rise and fall in the Midst of the Cylinder of Water, contain'd in the Barrel of the Pump, in such a Manner, that it rubs against nothing but a small Circle of Leather, well prepar'd and fix'd into a little Hollow at the Top of the Pump, on the inside over against O N. Through this Leather the Piston goes up and down, with the greatest Ease imaginable, and without any considerable Friction; for this Friction and Wear has been such, that I have known in Pumps (the Cylinder of which has been of Lead) that the Sucker has soon, (by the Imperpendicularity of the Stroke of the Piston, if I may so call it) wore away the Sides of the Pump, and render'd it ineffectual.

To bring this Engine to Perfection, that ingenious Gentleman assures us, cost him twelve Years Study, and a great deal of Money; and without this new Invention, it would have been impossible to have reduc'd the raising of Water to Weight and Measure, as he had done: A D L is the Rod of the Piston, upon which are slipt Weights, which are between E F and G H, to counterpoise the Water which is rais'd, and to keep the Piston upright between the two Pulleys B and C; V I is the leaden Pipe in which the Water rises, after it has pass'd through the Sucket I, which hinders it from falling back into the Barrel of the Pump; and this seems to be the best Method and Foundation for single Forces, and from which we may form any Compound Engine, though the Pullies may be omitted in all Crank or Leaver Work, &c.

THE single Piston for Pump-work being thus establishd, we come now to take a View of what may be said as to Valves, Clacks, &c.

ALL Valves, (as Monsieur Ozanan has it) are not made the same Way, which is the Reason they have different Names; for when a Valve is flat like a Board, it is call'd a Clack, and when it is round, and goes something tapering (which is by much the best, insomuch as the Air and Water in their Passage upwards has more Power in a hollow Concave, than it has on a flat one, to raise the same) it is call'd a Sucker; and these are the most in Use (especially in *France*) when they have a Tail which comes perpendicular out of the Middle of their Convexity, which Tail by its Weight draws down the Convex Part, to make it stop up close round the Hole, through which the Water passes, lifting up the Valve when the Piston is rais'd.

THESE Valves are useful to stop the Water in a Pump, keeping it from coming back again, when once it has been rais'd by Means of the Piston C D (*Fig. 5. Tab. seq.*) which must move up and down freely in the Barrel A B, and at the same Time exactly fill it, that the Air may not pass between, when the Piston is drawn up; and then when the said Piston is rais'd, since Air can't succeed in the Place of it, the Clack F will rise, and give Way for the Water to pass through the Hole, which it stop'd before; and on the contrary, when you push down the Piston C D, and press the Water which has been rais'd, the Clack F shuts; and since the Water can't get out that Way, it is forc'd out through the Pipe G H I, which communicates with the Body of the Pump; however, as the learned and laborious *Desaguiliers*, in his Notes on *Ozanan* (from whence this Account is chiefly extracted) has it,

it, this Pump would be imperfect, if there were not a Valve somewhere in G H I, suppose a little above H, to prevent the Water from descending, in Case of the Failure of a fresh Succession, which is often the Case.

OF Pumps, they are generally divided into two Kinds, the one is known by the Name of the sucking Pump, or Pump wrought by Suction, and the other a forcing Pump, which is effected by the Pressure of the Piston, or Pistons (for in compound Engines there are sometimes two, three, or four working in different Barrels, to cause a perpetual Ascent of Water) continually pressing upon the Water, and forcing it through a Pipe fix'd into the Side of the Pump, as was in the last Paragraph explain'd.

THE first of these two Pumps, and which is much of the same Nature as that describ'd by *Wallis*, and inserted in the last Chapter, is properly a sucking Pump, because it draws the Water through its own Trunk, where the Piston or Rod goes down; and of one of these Kinds, I have seen one, at a Person's whose Memory I shall always speak of with Honour, the late General *Webb's*, that drew Water near 80 Foot deep, that is, 25 Foot to the Clack at the Bottom of the Barrel, and the Rod or Piston about 55.

THE *French*, as also we and other Countries, cause a Hole to be made through such a Piston, from Bottom to Top, even from D to F, where they place a Clack, that when the Water is risen, by the raising the Piston (which in such a Pump is called a Bucket, done round with us with Leather, as has been before intimated) it may still rise higher when the Bucket is push'd down; for it will press upon the Water under it, which will push up the Clack F, and run up through the Bucket; and this Clack will immediately shut again, upon the raising of the Bucket, because the Water will press upon it, and then open as the Piston is sunk to make a second Quantity of Water (to succeed the first) and to enter into the Body of the Pump (which will at length, and in great Heights, and after many Strokes) be fill'd up to the End A, where the Water will run out: But to effect this the quicker and better, and to set the Pump at Work immediately, Men generally fill the Barrel with Water; and it must be noted, that the Valve or Clack below ought to shut close, to keep the Water from descending down, because sometimes the Pump may not be used for two or three Days, and it will be necessary to have it always full.

To proceed, that the Valve F (*vid. Fig. 5. Tab. seq.*) may play freely, the Rod E C of the Bucket must be fastned to it by Means of a bended Piece of Iron, as I C H, strongly fix'd to the Bucket; and it must be noted, that in this and all other Pumps, whether simple, or compound, that in case the Water lies low, you may make the Tube E G, which goes into Water 24 or 25 Foot long at least, for so high will the external Pressure of the Atmosphere raise the Water of its own Accord; *Gallileo* and others have indeed set down, that the Weight of Air will raise it 32 or 33 Foot high, or sometimes higher; but as that Air does not always act with an equal Power, but that Water rises and sinks as the Barometer does, sometimes higher, and sometimes lower; and as the Springs very often rise and fall, so that the Tube may not imbibe any Water at all, at least not enough for the Supply of this and other Pumps in the Summer Season 24 or 25 Foot above the usual Surface of the Water will do; and it is advisable also, to have a square, wooden, or leaden Box, with Holes in it, to prevent the Pebbles coming into it, laid 5 or 6 Foot lower than the usual Surface of the said Water is; but if it be not above 8 or 10, or any such like Quantity of Feet to the Water, then you may place the Bottom of the Barrel and Clack where you please.

THIS Pump is also call'd a lifting Pump, because it raises Water by pushing it upwards: Let A B be the Body of the Pump divided into two Parts A K, B I, of which B I must be in the Water, as also the Bucket or Piston C D, which moves upwards in this Part B I, by Means of the Rod F G, fix'd to the Point F, round which it moves together with the Piston C D, and its Rod E C, by Means of the Rod G H, *Fig. 8. Tab. seq.*

THE Rod E C of the Piston C D must be a Pipe continued in C D quite to D, (*vid. Fig. 8. Tab. seq.*) where it must have a Valve, and there must be also one at O; for if you push downwards, the Rod G H to make the Piston C D descend, the Piston pressing upon the Water, will force it into the Pipe E C, which will open the Valve at D, so that the Water may pass above it; then the Weight of the Water will press down the Valve, and hinder it from going back the same Way that it came: So when the Piston C D is rais'd, it will press the Water above it, and cause it to rise (by lifting up the Clack O) and go into the Part A K, where by its Weight it will press down the Clack O, and remain where it is: Thus will A K be fill'd by Degrees, till at last the Water runs out at the upper End A.

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By Means of this Pump, you may raise Water to a considerable Height; but it has one Inconveniency which attends it, and that is, that as the Rod F G must be always in the Water, which if it happens to be out of Order, it is hard to mend it: Besides, since the Rod F G moves circularly about the Point F, the Piston C D cannot rise or fall perpendicularly: For this Reason, the following Pump, which is rather to be recommended, ought to take Place, having nothing troublesome in it, but the Length of its Rod.

LET A B for Example be the Body of the Pump, which is to stand in Water as far as G H, and let the Piston C D have a Hole through it from D to F, where there must be a Clack to open when you push down the Piston C D, after you have rais'd it, to make the Water come in through the Clack E, which opens when you raise the Piston, and shuts when you push it down, to raise the Clack at F, which will give Passage to the Water, and then shut it self, as soon as you raise again the Piston C D; and the Clack E will open again at the same Time, and give Passage to the Water, which will afterwards be made to rise through the Clack F, by sinking the Piston as before: Thus continuing to raise and sink the Piston, the Barrel will be fill'd with Water, which will at length run out at the upper End at A.

THUS much of the sucking and lifting Pump, with the Improvements to be made to it: The second, and indeed the chief Pump now remaining, is the Force Pump, so called, for that it does, by the Strength and Force of the Piston, drive up the Water with great Strength to any Height required, when to the Rod C E is applied a Power as great as the Resistance, or, in other Words, strong enough to raise the Cylindrical Weight of Water, which is in the Pipe H I; and if there be a Clack at I to open and give Passage to the Water, when it rises through H I to enter into the Pipe I K, in which it will remain, because its Weight keeps down the Clack I, which must rise again, and give Passage to a fresh Quantity of Water, which will rise through the said Pipe H I, when the Piston C D is press'd down; thus by raising and sinking this Piston, the Water will continue to ascend in the Pipe I K, until it goes out at the End K.

AND this Kind of Pump (especially when it is compounded of other Powers of equal Strength and Force, as shall be hereafter taught) is of the greatest Use, by forcing of Water out of the

the deepest Profundity, from whence the Ancients could not possibly raise it, by any Art they had.

HAVING thus taken a View of the Theory of the Antlia or Pump, and its Parts, let us now proceed to the Practice of it, as it is set down by *Wallis*, and others.

AND the first Pump I shall give an Account of, is the Antlia, or so much fam'd Pump of *Ctesibius*, as we have it from *Wallis*, *Prop. XV. Cap. XIV.* of his *Mechanicks*, though it seems to be somewhat different from the Machine, so call'd by *Vitruvius*, *Lib. 10. Cap. 2.* as before hinted at.

THIS useful Instrument, (*vid. Fig. 1. Tab. seq.*) is made of a long Piece of Wood (or of more, if there be Occasion) cut out in the Inside of a Hollow Cylinderick Manner, and put down into a hollow Pit or Pond, the upper Part standing out of the Water, and the lower Part within the Surface of the said Pond or Pit; of which Water is to be understood, that it is not free from the Pressure of the Air, but by its Gravity and Elasticity subject to it.

SOMEWHERE in the Hollow of the Pump, let there be a cross Bar fix'd, in the Middle of which is the Hole D, through which the Water ascends; and upon this Hole is a Valve or Cover E, so fix'd, as that it will open or shut, according as it is press'd from above or below: Also let there be a Sucket let down from the Handle above, so fitted to the Sides of the hollow Cylinder, that the insinuating Air can't possibly pass by the Sides of it, which Sucket or Sucker has likewise a Hole F in the Middle of the Trunk, and fitted in the same Manner, with a Valve or Clack at G, as E was at D.

THESE Things being so fix'd, whilst the Sucker is drawn up and down by the Motion of the Handle; and when the incumbent Air, by which the Water that is under it is press'd into the Hollow of the Pump through E and D, and through the Valve opening at E, even to the Bottom of the Sucker, but not higher than C I, which is the greatest Altitude of the Equilibrium; and being free from the Pressure that is above, and drove on by that which is below, and *è contra*, whilst the Sucker is deprest again by the Motion of the Handle.

It presses also the Water that is under, that it may ascend through D; for the Valve at E being shut by this Depression, that at G is open'd, through which the Water (having overtopt the Sucker) is retracted again, and then it is, that the Work is to be repeated; and the Water having found its Way through

the opening at H, it there flows out, being succeeded again by Water rising again through D, in the Place of the retracted Sucker, and that continually.

BUT if the Altitude C D be greater, or if indeed it be not less than C I, in *Fig. 1.* which Ballance we suppose comes to pass by the Pressure of external Air, the Water can't ascend through D, nor can the Water at C be press'd any farther, than the other Parts A C B, and so the whole Labour of the Engine would be lost; but if D be under I, the Water will ascend through D to I, if it is not hindred, even to the Bottom of the Suckers, unless it be higher than I; but if the Sucker be drawn up again, so as that F or G overtop the Altitude I, the Sucker having left the Bottom, the Water will remain at I, in such a Manner, that if the Sucker should draw the Water, which was before at I, through F G, the Valve G being shut, it will lift up this also, and pour it out through H.

FROM thence it is (says a learned Author) that Quick-silver, and the Reason holds good in other Liquids, can't be rais'd by a Siphon, Syringe, or Pump, above 29 or 30 Inches, nor Water above 33 or 34 Foot, and all other Fluids, according to the Ratio or Proportion of their respective Gravities; the Cause being the same in all, namely, that all those Things which seem'd heretofore to be done by Suction, are truly done by Pulsion, suppose by the Air, or any other Pressure; and that there is nothing done by the Sucker, but drawing out the Air, to make Room for the Reception of whatever shall ascend by that Pressure.

WE have already noted, in *Lib. 2. Cap. 10.* of this System, this great Mistake that *Wallis*, and after him the Reverend Dr. *Wells* and others have labour'd, when they have imagin'd, or indeed have rather directly set it down as their Opinions, that Water could not be rais'd by a Siphon, Syringe, Pump, or any other Instrument of that Kind, above 33 or 34 Foot high, when it is notoriously known, that Water is and may be rais'd, even by a single Pump, above 100 Foot, and by Chain-work, &c. from the Depth of 200 or 300, as whoever will take the Pains, may see in the fine Buildings and Gardens of the honourable *George Doddington* Esq; one of the Lords of his Majesty's Treasury.

ON this Account it is, that I have exhibited the Profile or Section of this Pump, *Fig. 1. Tab. seq.* where the inside Part is open, and where the exact Manner of working it may be discover'd, still allowing what the learned *Wallis* and his Followers have

have said, that Water will not by any natural Means, or in other Words, will not, by the Laws of Hydrostaticks, rise above 33 or 34 Foot, or scarce to that always, unless it be forc'd by the continual and repeated Motion of the Piston in the Pump to ascend.

IT has been also observ'd already, as will be often repeated, that Pump-makers generally fix their Clack or Valve D, at about 25 Foot above the Surface of the Water, esteeming that the greatest Height, to which the Water will rise well, by the Pressure of the Atmosphere; at least they do so for Fear that the Water should sink at any dry Season, (as it often does, 2, 3, 4, or 5 Feet lower than it is usual) and then the Pump will be in Danger of being made useles.

THE same Members are made use of to compose this Pump, as are for Pumps of any Kind; but because the Sucker D, which is made of Brass just so, as to fit the Cylinder of Wood, Lead, &c. in which it works, must be always in the Water; it is necessary, that the said Sucker have a large Hollow in the Middle, and have a Clack at Top as G, through which the ascending Water may pass, when the Rod or Piston, with the Sucker, is descending; which Clack or Valve will immediately, in its Ascent, lift up the Water higher and higher, till by the Repetition of the Stroke, the Water is ascended to its intended Height at H or I, which may be either more or less, as the Length of the Rod (to which the Sucket or Sucker, and which is also sometimes call'd the Bucket) is.

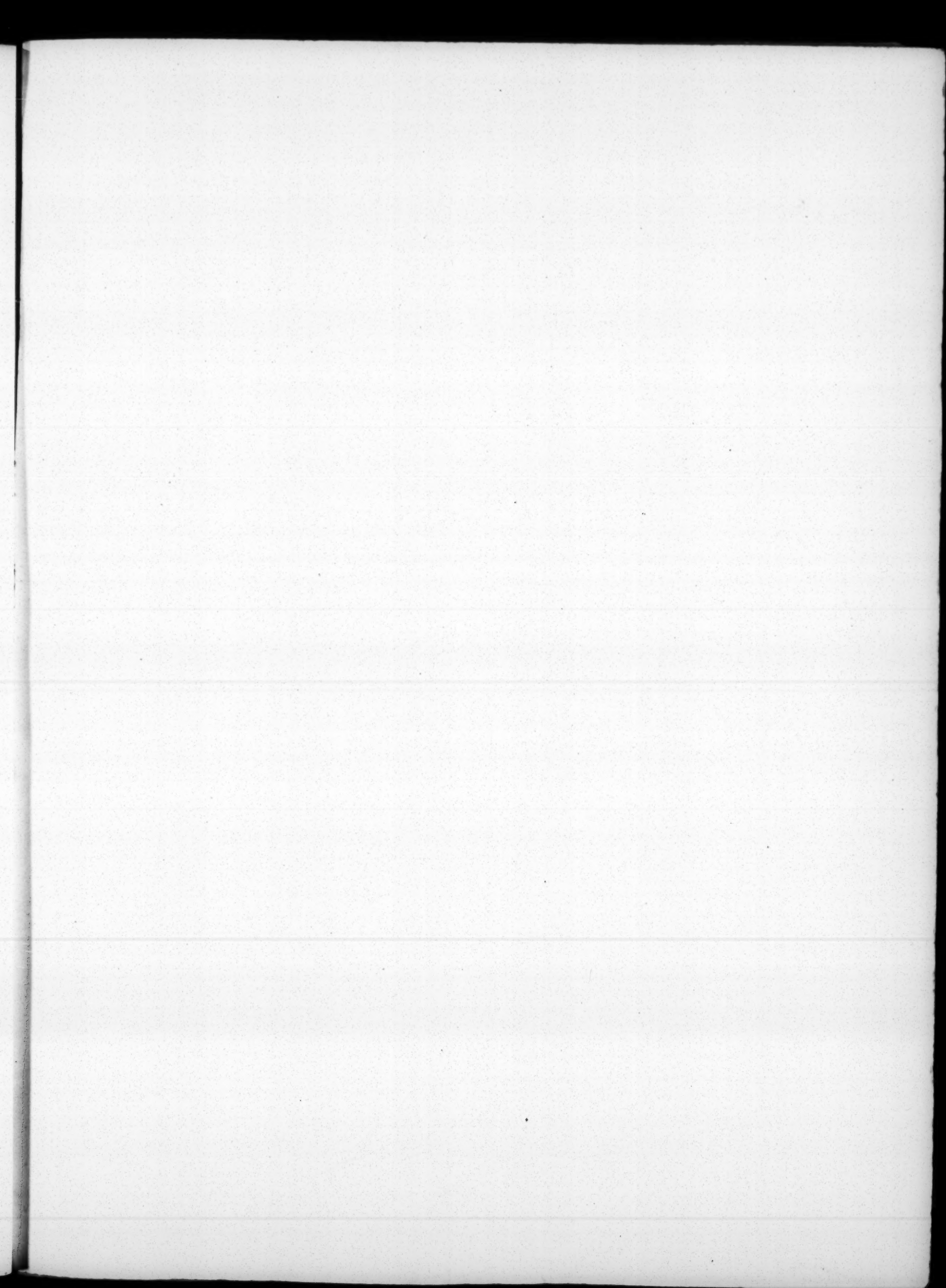
IT may be thought, that this Bucket or Sucker, working always in Water, may go very heavy, and that it won't be in the Power of a single Man to work it; but we have already demonstrated, that we don't feel the Weight of any Bucket, and the Water which is in it, when we draw, till it begins to rise out of the Water, because the Water in the Bucket, or that which rises by it, is of the same specifick Gravity with the rest of the Water; and tho' this Bucket or Sucker be of Brass, yet as it is very hollow, and not large, the Difference from an *Equilibrium* is but little; and as the Bucket or Sucker is hollow on the inside, by the opening of the Valve or Clack therein, upon Depression, the Valve or Clack at FG, is shut, and the Water forced to ascend, contrary to its own Nature, to the greatest Height.

To conclude what we have to say on this Head, if these Things can be effected by a sucking Pump, with much greater Ease.

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Ease will it be done in a forcing Pump, as describ'd in the Beginning of this Chapter, where the Stroke of the Piston is so great, that by a double, treble, or quadruple Repetition, as is in all compounded Engines, the Water may not only be throw'd one, but even 200, 300, or 400 Foot high, as will be more particularly seen, when we come to treat of compound Engines.

It is observable in one of the Pumps before describ'd, the square Leads, that Sir *Samuel Moreland* prescribes for to hang on the Rod or Piston, can't be us'd; because, as the Piston works always in Water, they will hinder the Ascent of it up, unless they are hollow in the Inside; however, to keep the Piston steadily perpendicular, the two Wheels may be made Use of that are at the Top. I have also added a new Sort of Handle, which makes the Pump go so easy, as that tho' you draw the Water three or fourscore Foot deep, yet a Child of 10 or 12 Years old may work it; besides which the Piston will move thereby more perpendicular, and with more Ease between the two Wheels, than without them; and all that I have to add is, that you load the Bucket or Sucker with Lead, or other Weights, so much as that it may descend in the Water with Pleasure; it being certain, that in this Sort of Pump it is much harder to depress than raise the Piston. But to come to a more particular Explanation of this Pump, the Valve D is suppos'd to be 25 Foot above the Surface of the Water, in the Well or Pond, which will rise by the Pressure of the Atmosphere, to that Height; and over the Hole D there is a Valve, E so plac'd across, as to open or shut, according as it is press'd from above or below; as also a Bucket, at F G, let down from above by the Rod or Handle (so fitted to the Sides of the hollow Cylinder, as that the Air can have no Passage between) which also hath a Hole in the Middle of its Bottom, and a Valve at G fitted to it, as hath DE. Things being thus ordered, while by moving the Handle the Bucket is drawn up (the Air being upon it, and by that Means there will be a less Pressure of Air upon the Water below the Bucket) the Water in the Well being press'd by the ambient Air, will be forc'd up into the Hollow of the Pump, through the Hole D (as was mention'd in the last Kind of Pump) opening the Valve E, as far as the Bottom of the Bucket, provided it be not higher than I, the Top of the *Equilibrium*, as being free from any Pressure from above, and thrust up from below; but on the contrary, by turning the Handle the other Way, the Bucket is press'd down, and presses the Water
immedi-



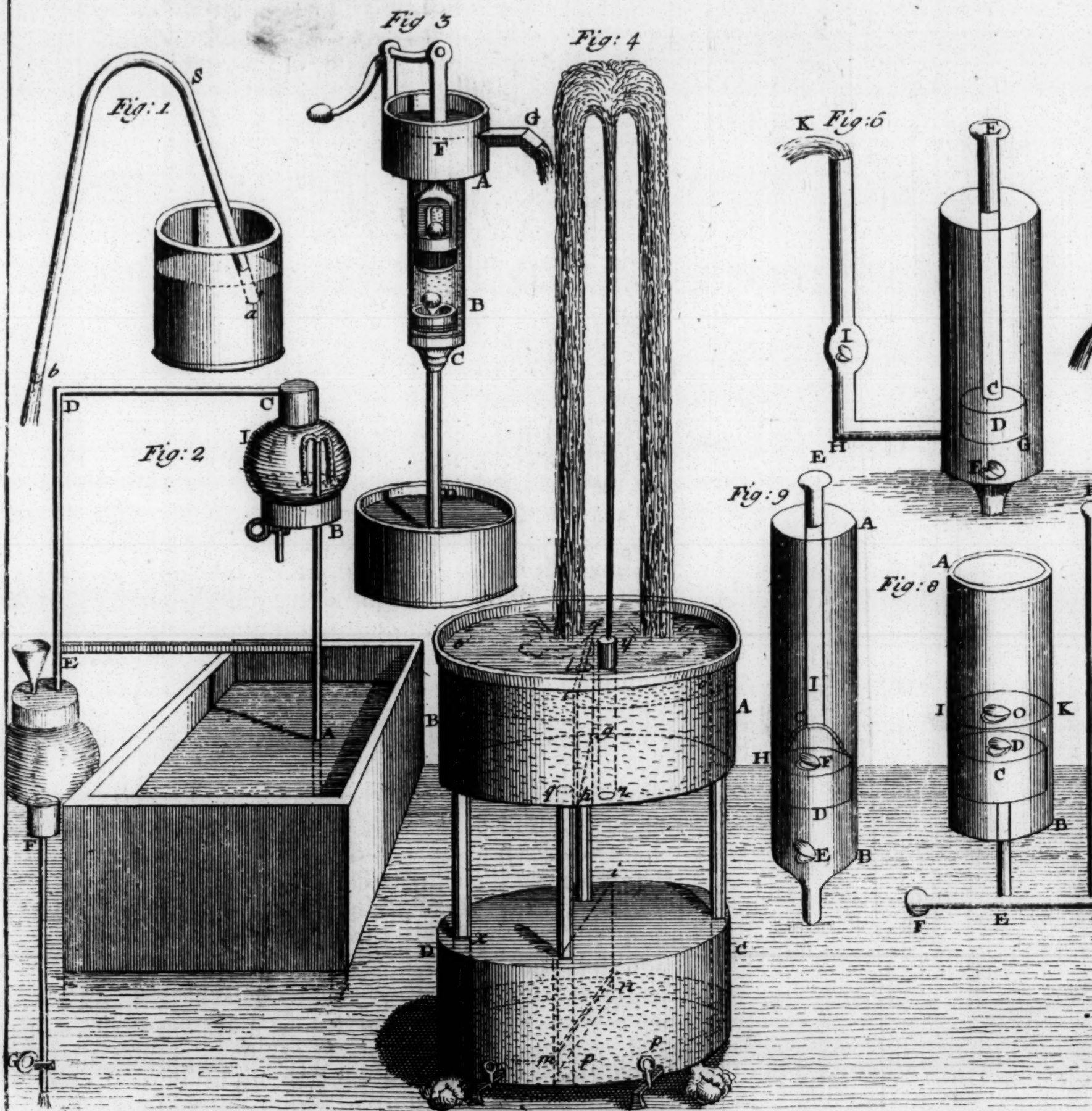
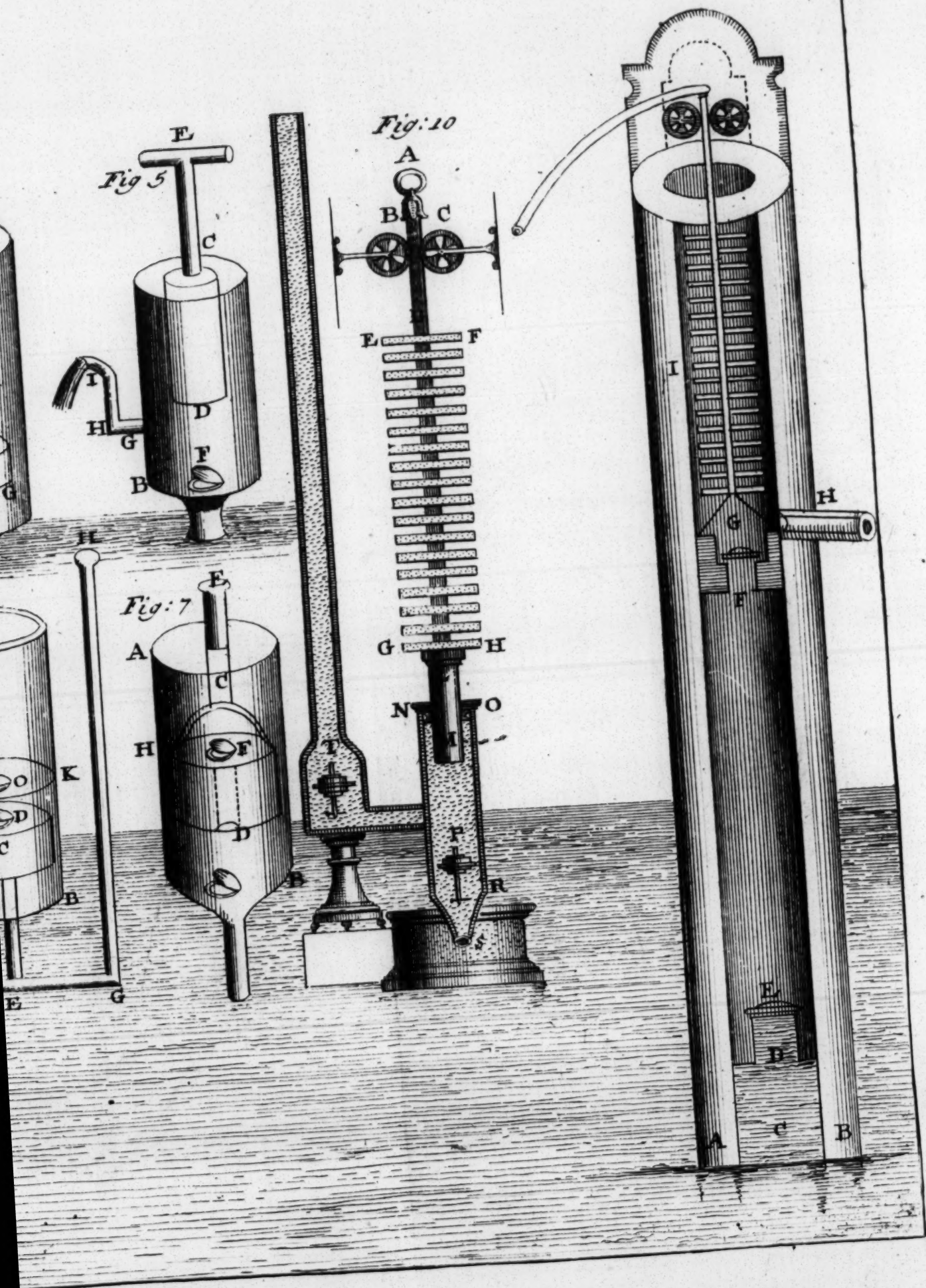
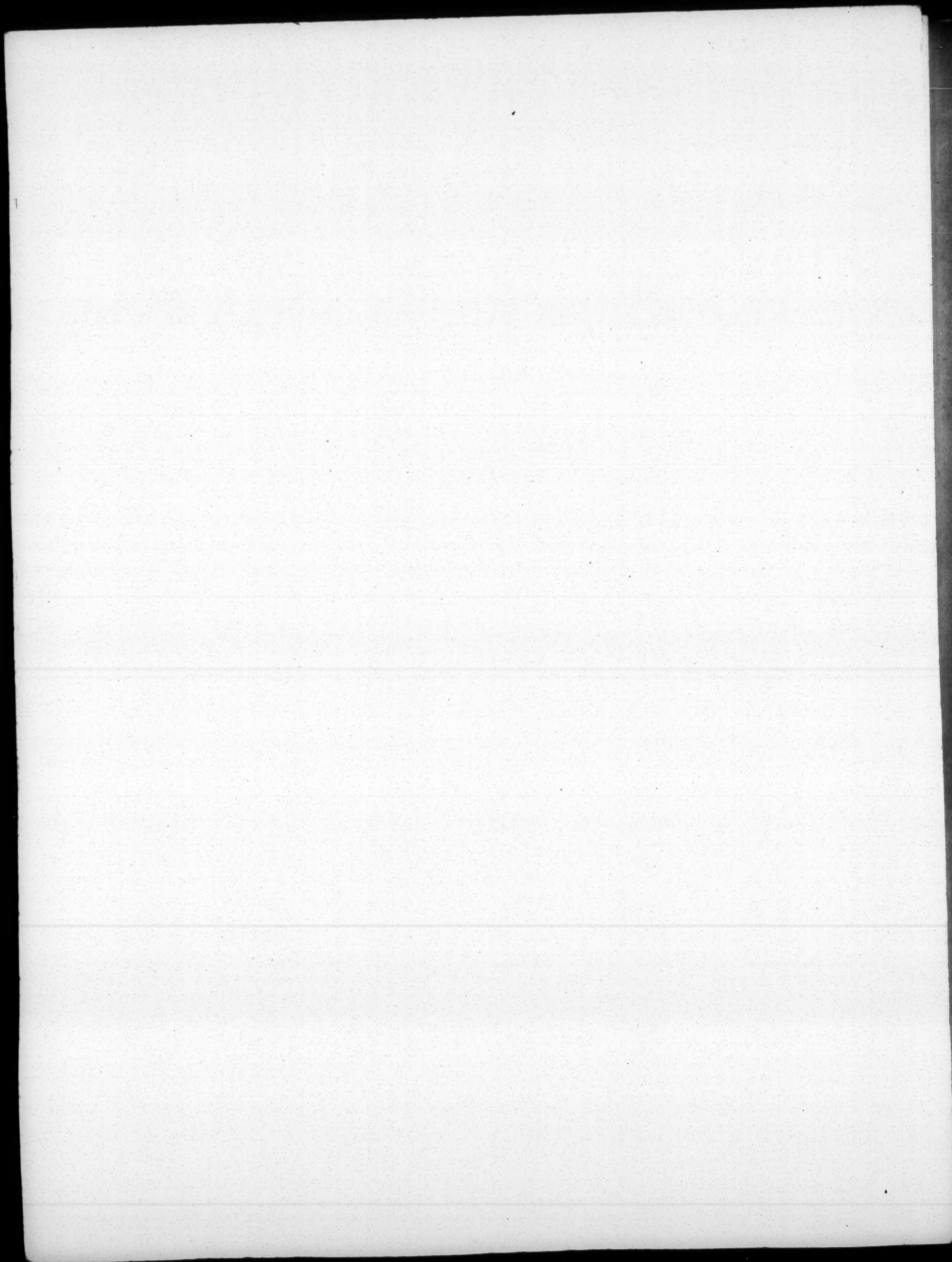


Fig: 11





immediately under it, which ascends through G D. By this Depression E is shut, and G opened, through which the Water having got above the Bucket, is drawn up with it; and when it is drawn back (the Valve G being shut) and finding Passage, flows out at H, which, as will appear by the Figure, is much higher than the Bucket; and that consequently all the Piston and Bucket must work always in Water, which in the preceding Figure it is not supposed to do it there, raising the Water no higher than H, tho' this raises it to L or M, as there is Occasion: The Bucket of the other does indeed work in the Water; but then its Stroke is but short, and the Rod is but just immers'd, the square Pieces of Lead hindering its Ascent any higher.

As to the Handle, just above, O in the Pillar of the Pump, is a Pin, on which the Handle P is fix'd, which moving the Arm Q, which is fix'd to the other Handle R, by Rivets at *a* and *b*, the upper Handle or Movement Q is fix'd a Pin at A, where it gives Motion to the Rod or Piston; and so the Bucket G, at the Top of which there is a Valve that opens and shuts. Note, There are Holes at *f b*, to which you may remove the Arm Q, as you see Occasion.

THIS Surface of the Water is suppos'd to be from C D to G F, to the Height of the Atmosphere, when Allowance is made for the sinking of Water in dry Weather; and that it may spring out hastily there, even 25 Foot above the said Surface, as has been before noted; and this Kind of Pump is by some called the Atmosphere Pump.

By Means of the Spout L, you may pump up Water into a Cistern 7 or 8 Foot above the Ground, and the Rod S may be 40, 50, 60, even to 100 Foot long.

THUS much of the single common Pump; all that I have to add to it is, That this new invented Handle, which I think makes it go much easier than the common Way, is to be seen at my very good Friend's, *Borlace Webb Esq.* at *Biddesden Wilts*, where they draw their Water above 80 Foot deep, by the Help of this Handle only, and that with one single Person.

BUT as these Pumps are made different Ways, and are sometimes double, treble, and quadruple, I shall, in the Course of the ensuing Treatise, set down some of the best Sorts I have seen or read of; and the first is a double Pump, as we have it from *Bockler*, Page 35. Fig. 143. (vid. Fig. 2. Tab. seq. of this Book) and which I am told the York-buildings Company use, (though I have not seen it) which for Cheapness, and the Quantity of Water

ter it will produce, is of most excellent Use, and is wrought only by two Men.

THE Pistons E E are let down into, and strictly fix'd in the Concave Tubes D D, and are there mov'd; but so that no Air can pass by the Sides of the Pistons, into those Tubes; the Cross-beam Mark B B is also fastned into the Post A, and mov'd on a Pin key'd into the Middle thereof, at C, from the Motion of which the Valves or Clacks at F F, open and shut, and produce the same Effects, as in other Pumps.

THE next Pumps I shall produce are taken from an *Italian* Author of great Repute in Machines, the one is a double Pump, drove by a Man going in a Tread-wheel, which giving Motion to the two Cranks G G. by the Rotation of the Axle-tree H F, fixt as they are in the Frame of Wood I. I. gives Motion to the two Pistons E E, which descend alternately, and either lift up the Water by the Means of the Clacks and Valves B C D, the Water entering in at the Arches A. A.

THE chief Things which I have to observe from this Draft, is the great Care this *Italian* Author has taken to make these two Pistons fall perpendicularly, by framing them into two square thick Boards at *b. b.* and the Reader will easily discern, that by Means of the Rings E E, in which the Cranks G G work, are design'd to facilitate that perpendicular Stroke; this Figure is seen in the following Table.

THE next double Pump I shall Figure out and describe, is taken from the same Author, where is figur'd a Man standing (at Q Q.) upon a Frame of Wood, and there being a Center at R, whereon there is fix'd a Vectis or Leaver, at each End of which there is a great Weight fix'd, mark'd S. S. which counterpoise each other, and are of a Weight sufficient to force the Water up through the Elm or Lead Pipes A A; so that by the alternate Motion of the Man on Q Q, and the Center E, the two Pistons T T succeed each other in Pressure downwards, and Ascent upwards, forcing up Water in the Coffer B, where there is Buoy; which Coffer is fix'd on the Frame H, and lies sloping for the Water to run out, with the greater Pleasure into the Cistern K.

IT appearing by the Draft, that the Water is rais'd but a little Way, I take Notice, that that was an Imperfection in the *Italian* Author's drawing, which I was not willing to alter; but 'tis very certain, that this Pump, be it either us'd by Way of Suction or Pressure, will raise the Water as high, and with as much Ease, as any of the Pumps yet mention'd: So that supposing you allow

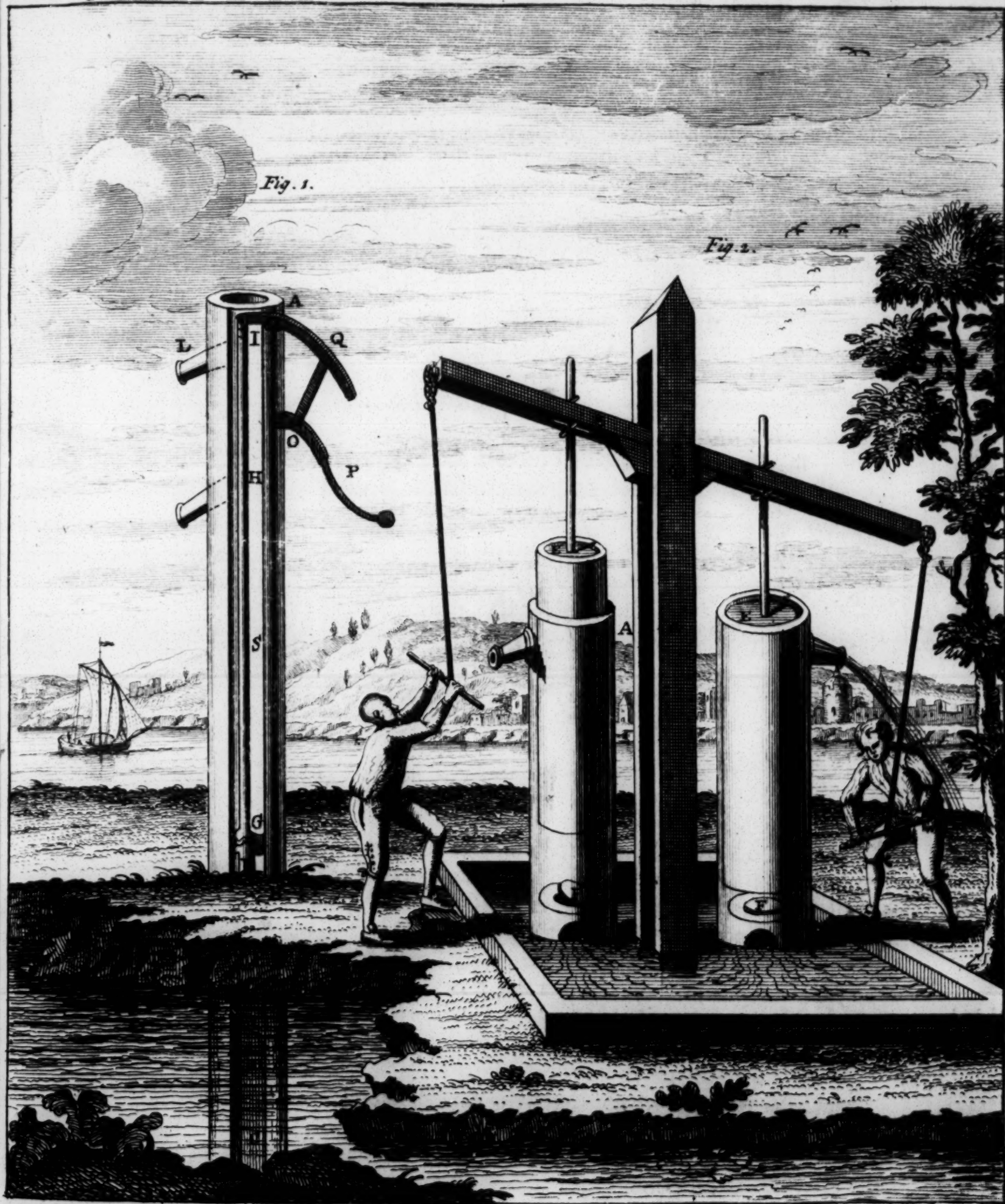
D D



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DD to be 25 Foot, the least Height of the Atmosphere, the Frame HH, on which is fix'd the Coffe B, may be plac'd at any Height you please, even to 100 Foot, provided the Pistons TT be of that Length; but then it will be a considerable Time at the first pumping, before the Water arrive into the Coffe.

I have another Thing also to observe, which is, that there is at QQ, and all along the Piece whereon the Man treads, an open Groove for the Piston TT to work in, which going through the Top of the Coffe at MM, maintains a constant perpendicular Stroke, which is what all our Engineers, by Methods sometimes very shocking, endeavour to do, to make the Pistons fall perpendicularly, and to prevent that Friction, which is almost unavoidable, in most Kinds of Movements in Pump Work.

I might in this Place have added a great Number of other Kinds of Pumps, which are us'd in *England*; but that I find this Volume is swelling beyond its intended Bulk; so that I shall desist saying any more, except I do it in the Notes adjoining to this Book.



C H A P. XXIV.

Of the CHAIN-PUMP.



Might, from *Bockler* and others, have produc'd almost an infinite Number of Drafts of Engines, which are plac'd under the Terms of *Budromia*, *Hydrotechnema*, &c. the first signifying the Methods of raising Water by Buckets, and the other by Globes, or Figures of any other regular Shape, fix'd to a Rope, which Rope being fastned at each End, and passing through an Elm or other Pipe, which reaches from the Bottom of a Well to the Height to which the Water is to be convey'd, brings up the Water along with it; but these Kinds of Engines being out of Date, I shall pass over them, and confine my self to two Sorts of Engines only, which are reducible to this Head; the first is the Chain Pump of *De Caus*, from which it may be supposed, the Reverend Mr.

S f

Holland

Holland first took his Model. And the last is a Chain Bucket Pump, the excellent Invention of a poor honest Countryman of our own, I mean Mr. *George Gerves*, whose Engine I think very justly excels any Thing of this Kind ever yet invented.

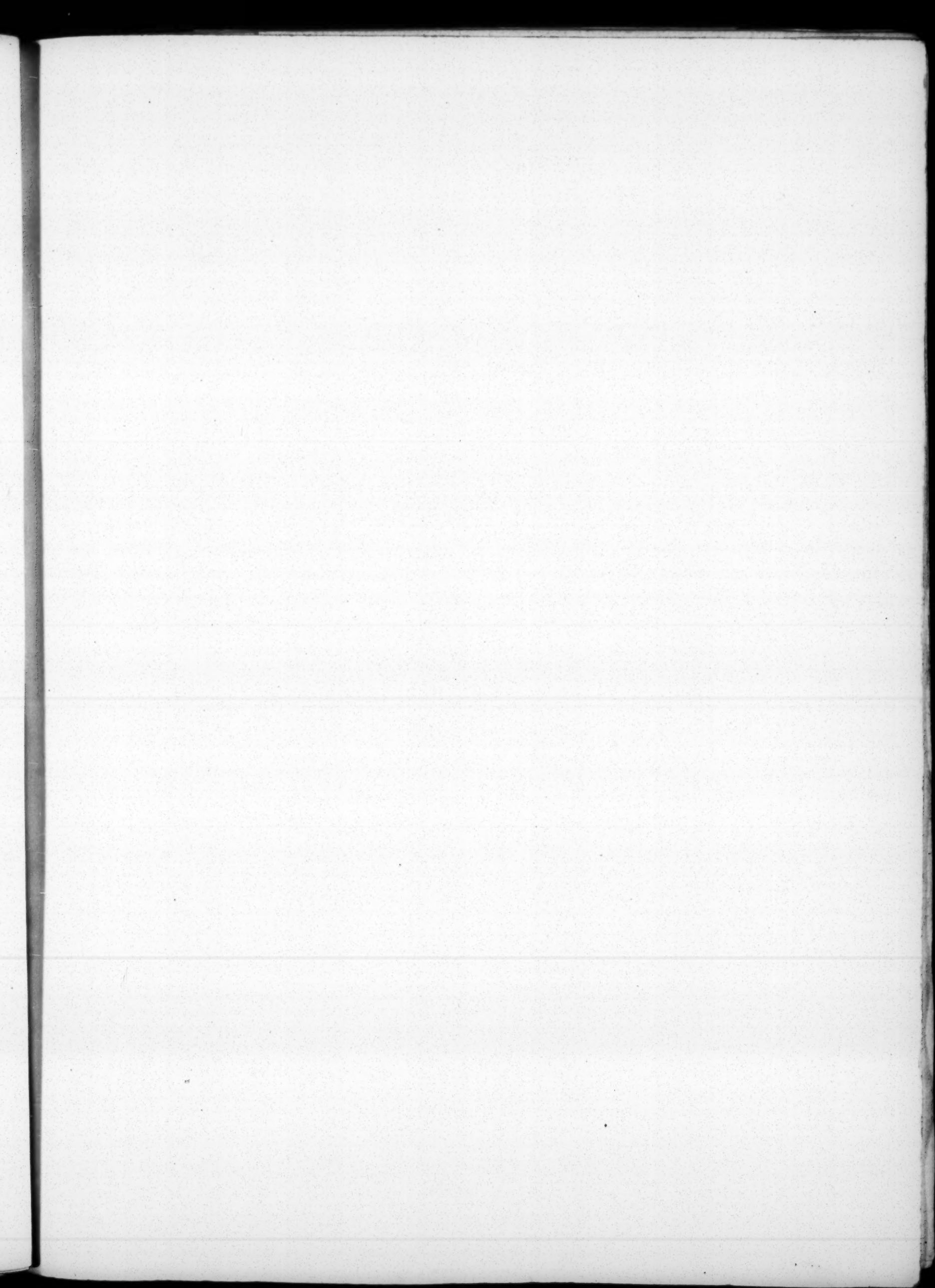
THE Description of the first Pump is found in the *English* Edition of *De Caus's forcible Movements*, Page 34. Fig. 26. What he recommends in it to be of great Advantage, is, that the Forces rise and fall perpendicularly in their Barrels. It is (says he) easy to comprehend by the Figure (*vide Plate 16. Page 316.*) that there are four Places in the Arbor, which are hollowed or channell'd, and in the Half of the Channels there are Pinns A E, encountering with Pinns which are in P H, which make them to ascend and descend, and in descending, they raise one without hindering the other, or being hindred by any other Pinns, which are in the Roll mark'd P H, because they pass by the void Place of the Channel, or rather Collar mark'd D D, C C, by Means of the Chain and Pully K K: And so they rise and fall each in his Turn, and force the Water with great Violence to fifty or sixty Foot, and some to one, two, or three Hundred, as Occasion requires; and this Machine may be made to go, either by a Horse or Horses, or by Water; but being heavy, requires a great Force to be applied to it.

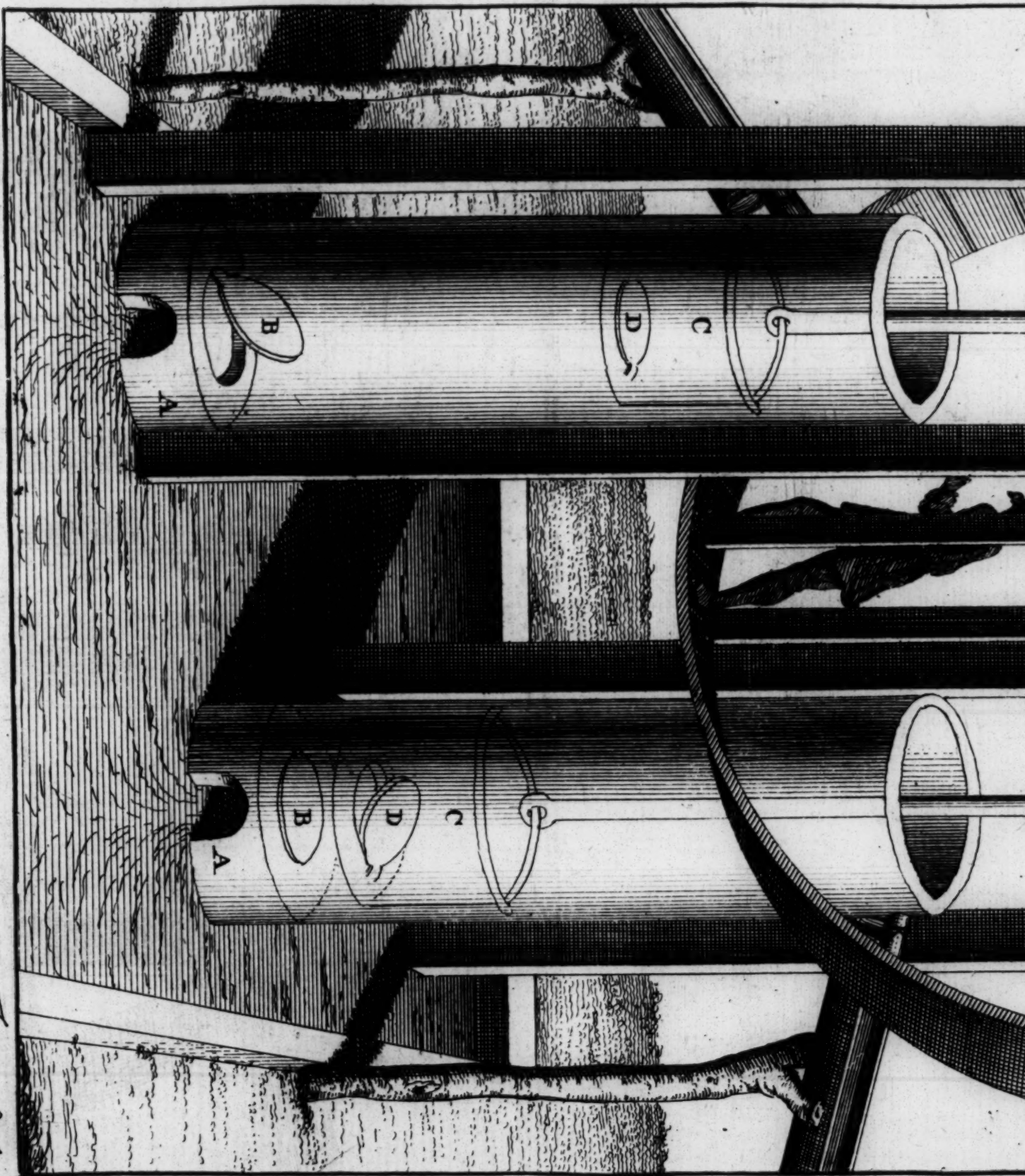
I have seen that of the Honourable *George Dodington* Esq. at *Gunville, Dorset*; as also that of his Grace the Duke of *Queensberry*, at *Amesbury, Wilts*, with Works of the same Kind at other Places; but there is such a vast Quantity of Timber Work, and the Machine goes so very heavy, is so noisy, and so apt to be out of Order, that I thought it not proper to make any more Observations about it.

THERE are of these Chain Pumps in the curious Collection of the Right Honourable the Earl of *Islay*, that have 6 or 8 Pistons to an Engine, but four is I think generally sufficient, which is all I have to add to this Engine. The last Rope or Chain-Engine I am to mention in course, is that lately invented by Mr. *George Gerves*, at Sir *John Chester's* at *Chicheley* in *Buckinghamshire*, which for its Curiousness and Uses, and going with less Water, is allow'd to exceed any Machine yet invented. *Vide Plate 17. Page 316.*

I shall not take upon me to give a particular Description of this Engine, tho' I have had it several Times in my Hands; because I am unwilling to anticipate the Account of it, just now a publishing by the Inventor himself.

IN general, it is, and may be called a *multiplying Wheel Bucket Engine*, which moves continually by a small Fall of Water, without the Help of any Man, Water, Wheel, Wind, or Fire, purely





James Watt

G. n. 314

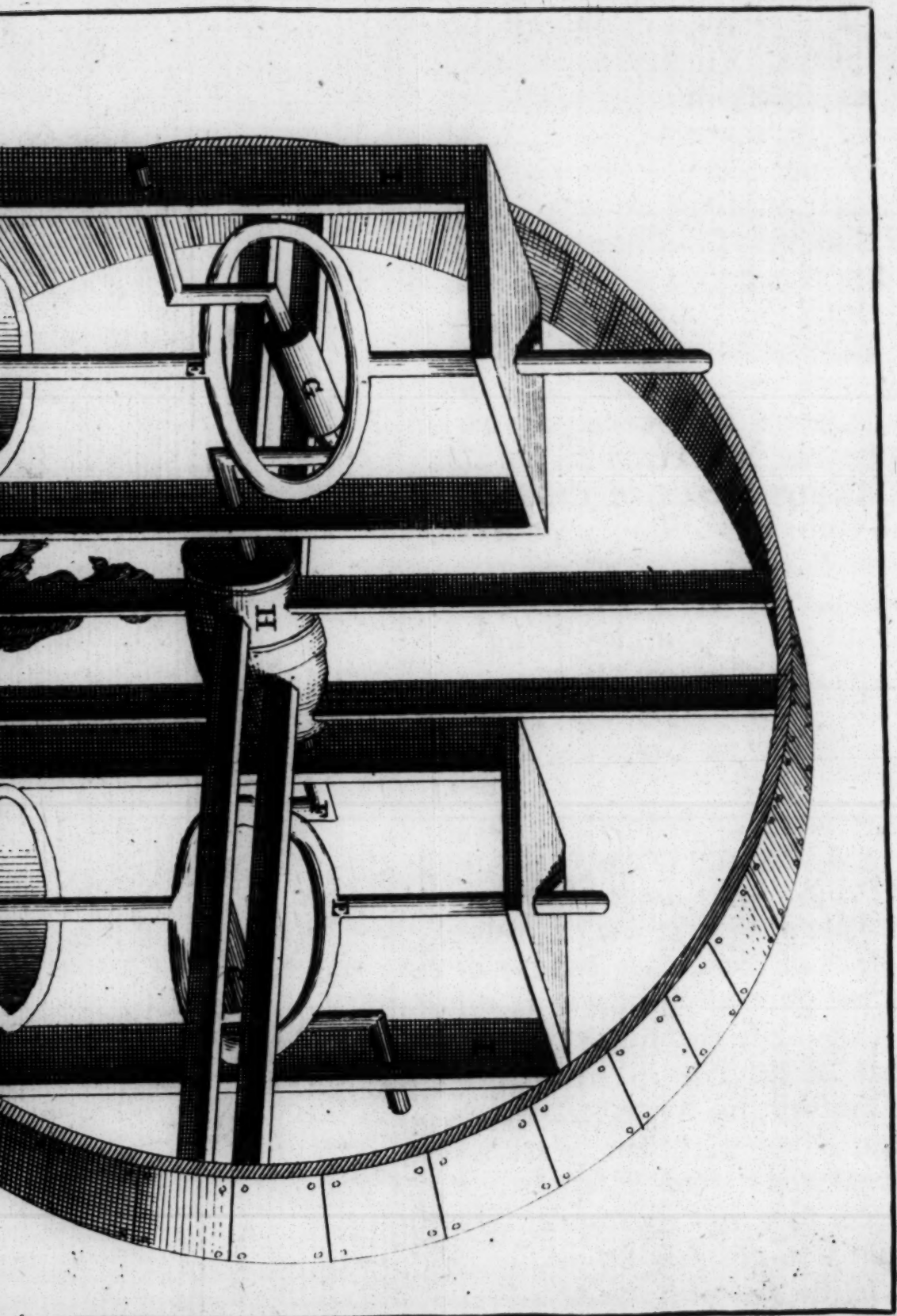
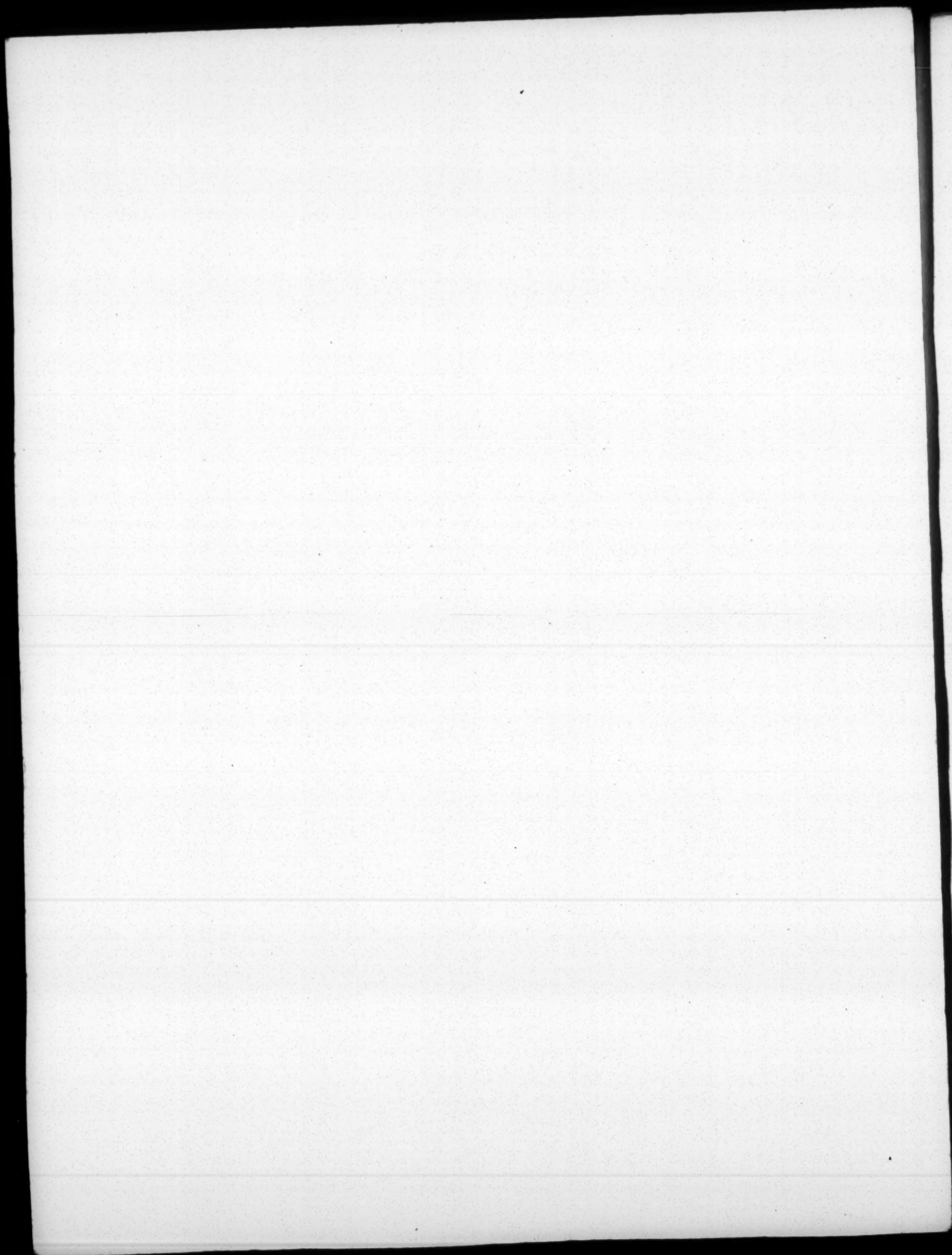


Plate 14



purely by a Mechanical Force, founded on the Principles of the *Statera Romana*, or Steel-yard : For as the Water runs from the Spring A, by the prick'd Lines B, into the Cistern C, there the two Buckets D D meet, and are fill'd at one and the same Time; and the lower or larger Bucket D being several times heavier than the upper or smaller one, preponderates and raises it up to a Cistern somewhere behind at N; and at the same Time that the little Bucket empties it self above, the great one does the same at E, the Water whereof goes out at the Waste F. And by this it is evident, that as the great Wheel at the Top mark'd Q, is proportionably larger than the Diameter of the small Wheel on which the great Bucket runs P; so the great Bucket holds so many times as much as the small one, which makes it to preponderate and raise the small one. And again, when they are both empty, the small Bucket being upon the large Wheel Q, being suspended on a Fulcrum or Prop, which I call the Axis O, by the Laws of mechanical Gravitation sinks down, and raises up the great Bucket now emptied of Water, in order to their meeting to fill again the Cistern C.

It has been already intimated, that an Attempt will not be made at a full Description of this excellent Machine, which is regulated or bridled above by several Works towards the Top; and I only add, that Mr. *Gerves* has of late so considerably improv'd his Notions in this kind of Work, that he omits several of the Members of which it is now compos'd; to use the Words of the ingenious Mr. *Henry Beighton*, F R S. the Motion is so quiet and steady, and there is so little *Friction* in it, that it is likely to continue an Age without any Repair, and to be of the greatest Use in raising of large Quantities of Water to any great Height (according to the Current or Fall that gives it Motion) for the Supply of Noblemen or Gentlemens Seats. And I add, that as there is no Engine that I ever saw, which appears to me by the Model to go easier and quicker; so there is none that can go with so little an Expende of Water as this will, and will indeed do where no other Engine (let the Movement be what it will) can: Even a Straw full of Water will do it, the Motion only being the more leisurely, in Proportion to the Quantity of Water which supplies it.

To be more plain, if the Spring is very small, the two Buckets which fill at one and the same Time together, may be two or three Minutes, more or less, a filling; where, if it be a strong Spring, it may fill in half an one, or less, but still they will fill; and as soon as they are full, be it at more or less Distance of Time, they will both begin their Journeys, one ascending, and the other descending.

I have not had Time to make any particular Computations of the Quantities of Water this Machine will raise, tho' it is plain by Inspection, that not above two Thirds of the Water at most runs to Waste, and that if there be an half Inch Pipe of Water running from the Conduit A, yet the Machine will be always in Action; only whilst the two Buckets are filling, it stands still; and one may dare to challenge any Engine or Machine that was ever made, to go with so little Water as that of two Thirds of an half Inch Pipe, since there is no Spring, where or howsoever situated, but will work it: And there is this to be said more, that for every Foot Fall you have from the Cistern C, to the Waste B, just so many times 6 Foot high will it raise the Water to the Cistern it is to be emptied at, at N. Supposing then that in Plate the 17th, the Fall to be 6 Foot, the Water will be rais'd near 30 by this Engine. But a more exact Account will in a little Time be publish'd by the ingenious Inventor himself.

I now go on to Chap. 25. L is the Plan of the House, where the Engine is plac'd, K K is the Roof, R R are Windows lighting the Engine.

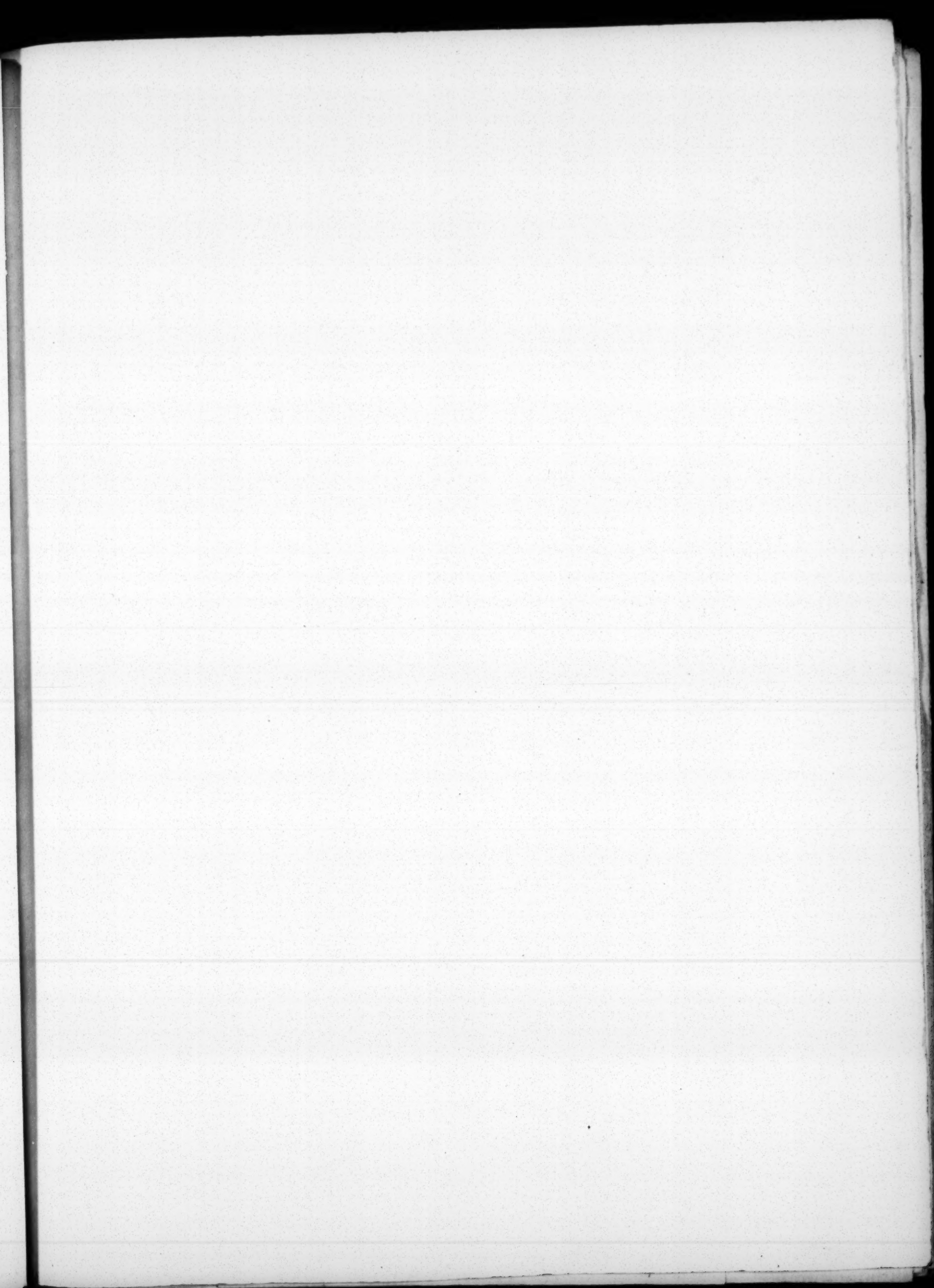


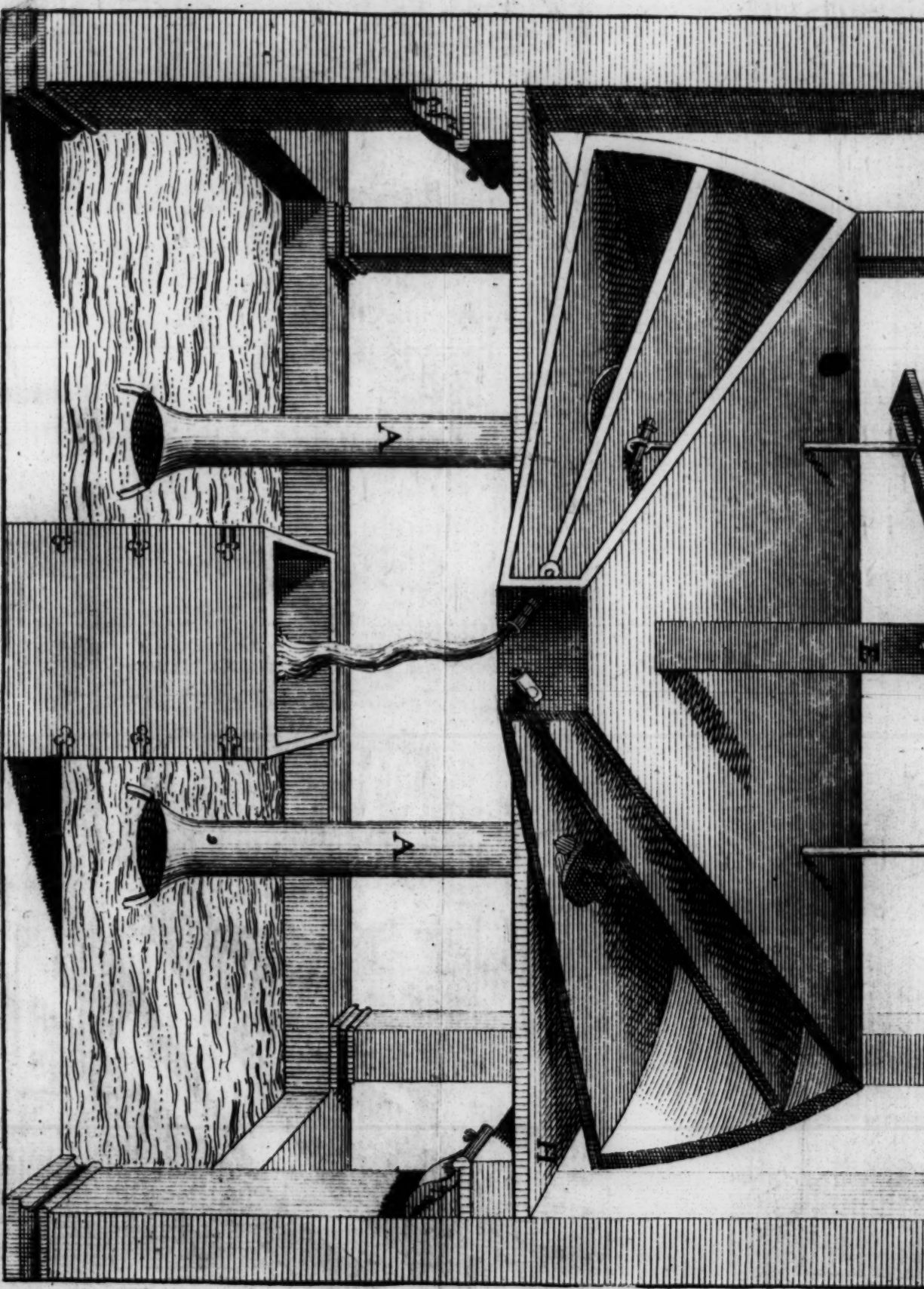
C H A P XXV.

Of Crank Work, and of regulating Engines.

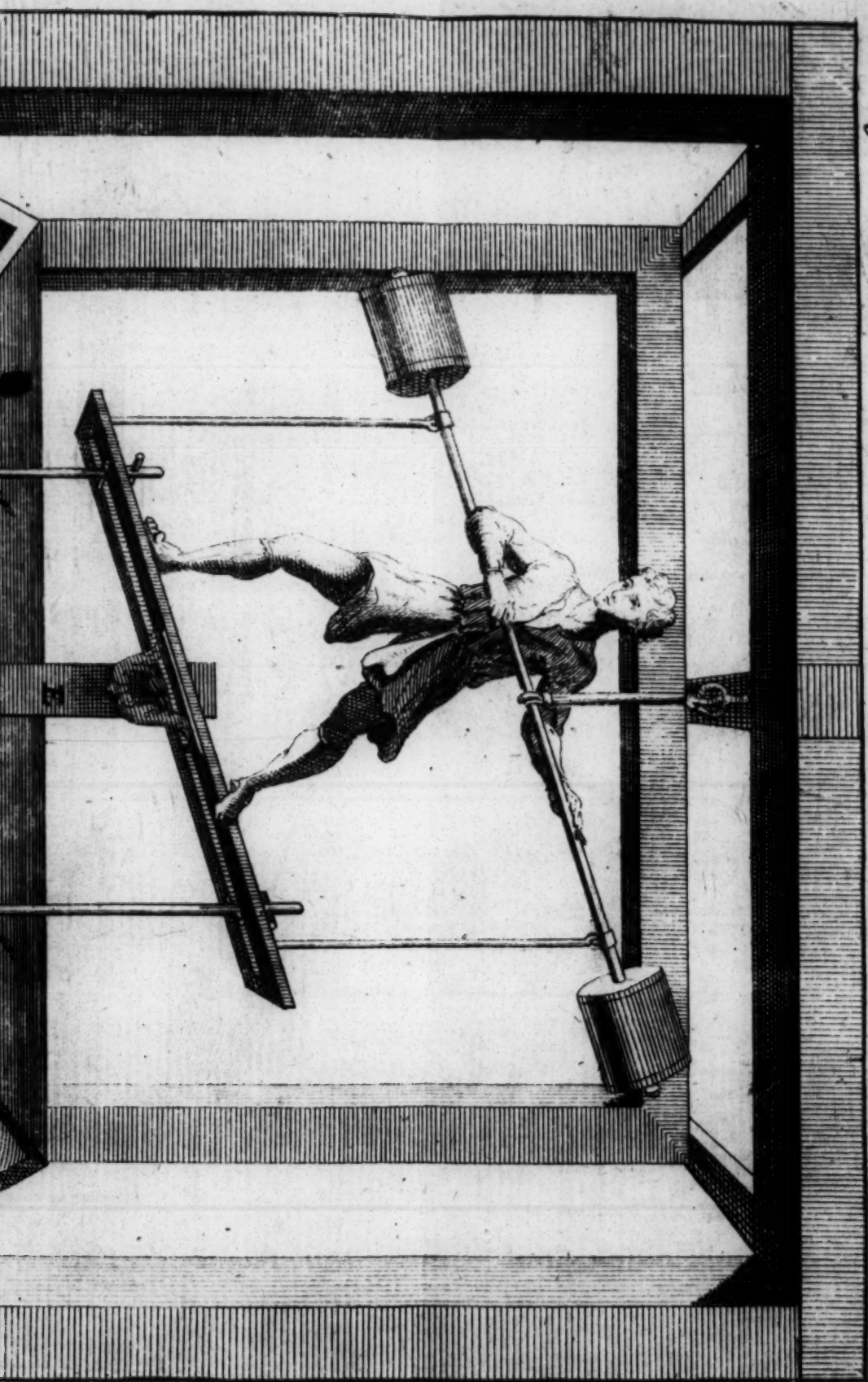


WITHOUT Doubt the Use of Cranks in all Engines, is of as long a Date, as any Power that belongs to Machines of this Kind, especially double, treble, and quadruple Pumps. *Bockler* in his *Theatro Machinarum*, and a great many other Authors, have given the Profiles and Description of several Kinds of them, some of which I intended to have inserted in this Place, but that I had not Room, this Volumn beginning to swell beyond its first Intent. The *Cochlea Quadruplex* that *Bockler* makes mention of *Page 29. Fig. 92.* and which, he says, is to be found in *Agricola*
de

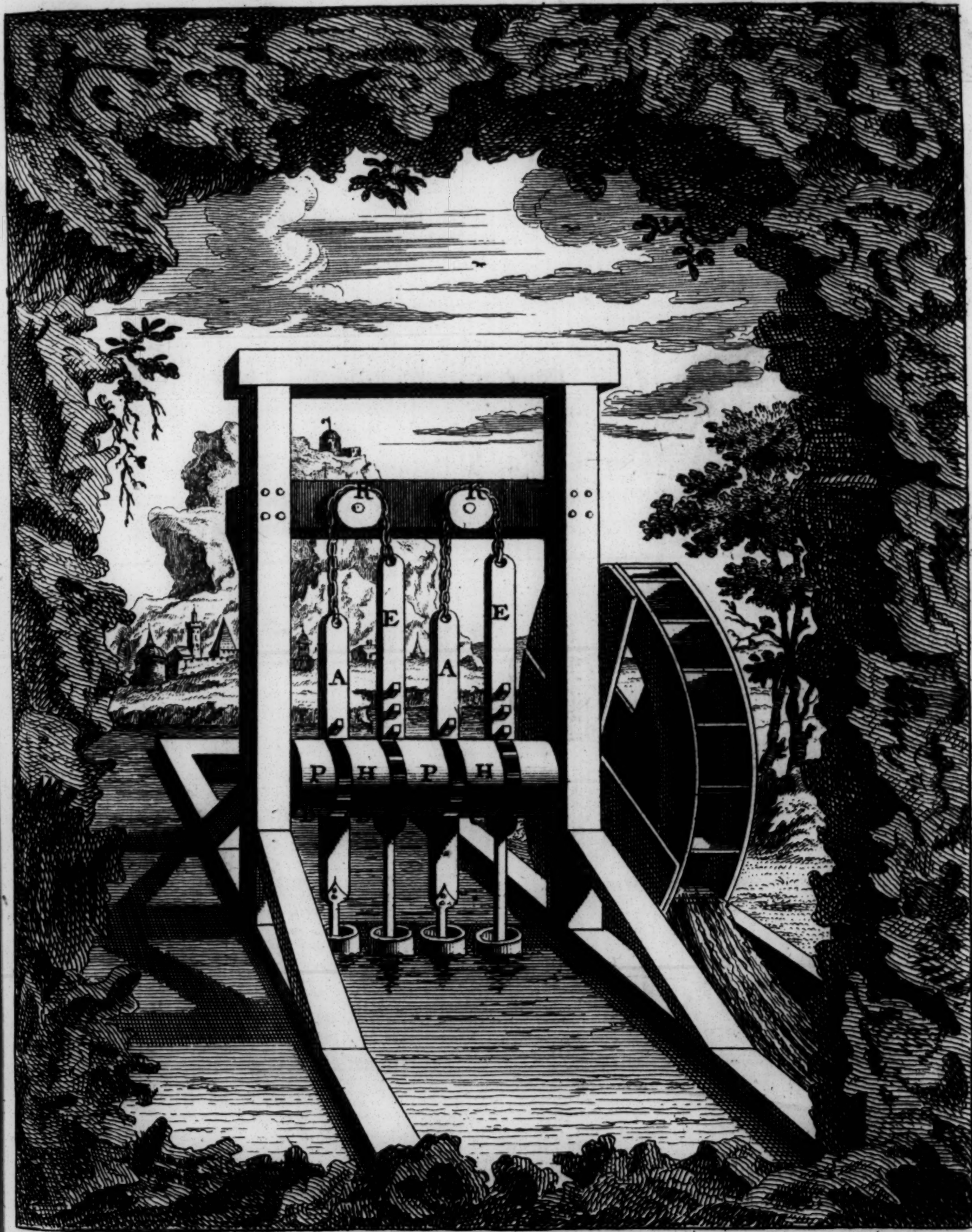


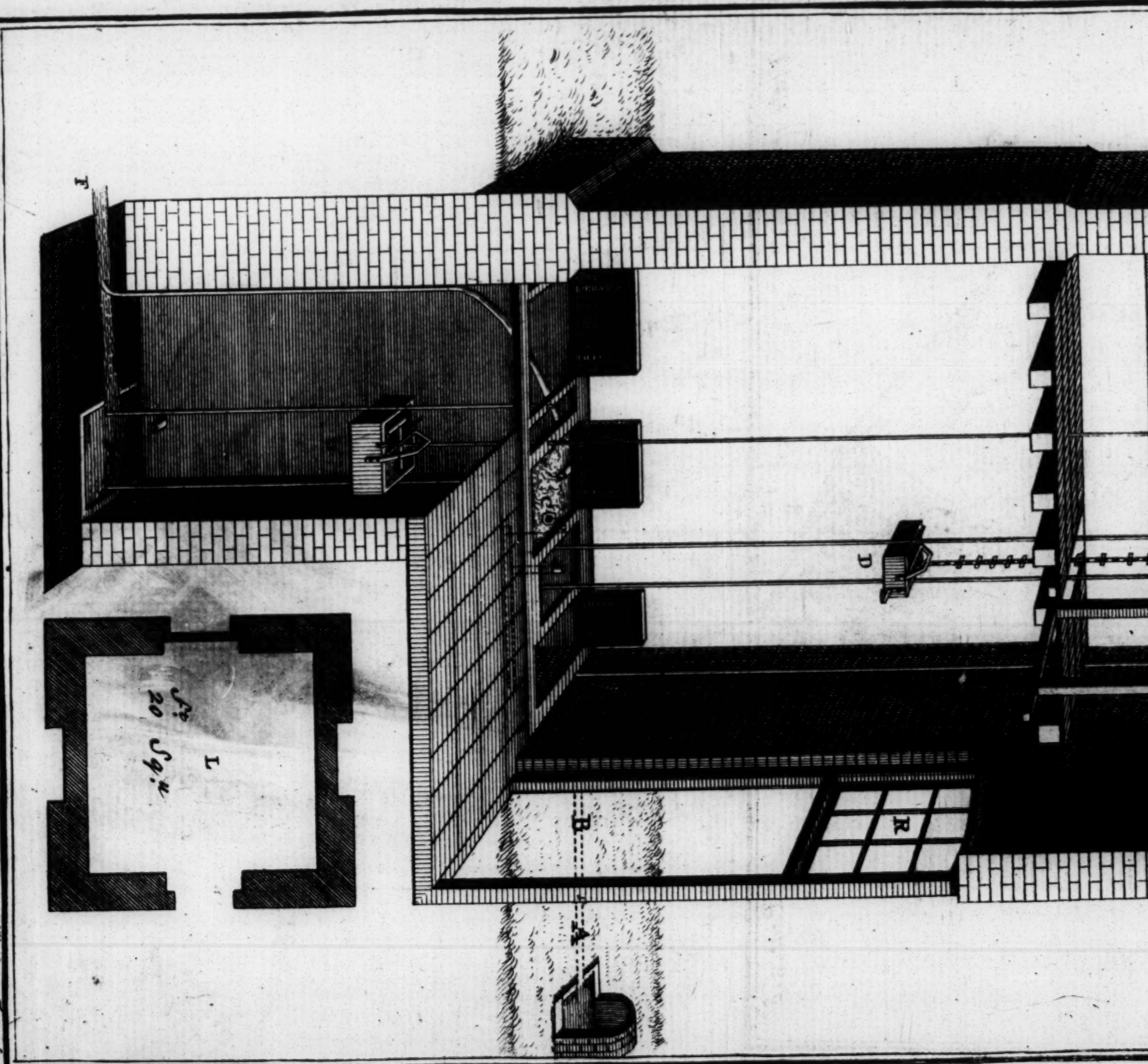


J. Smith





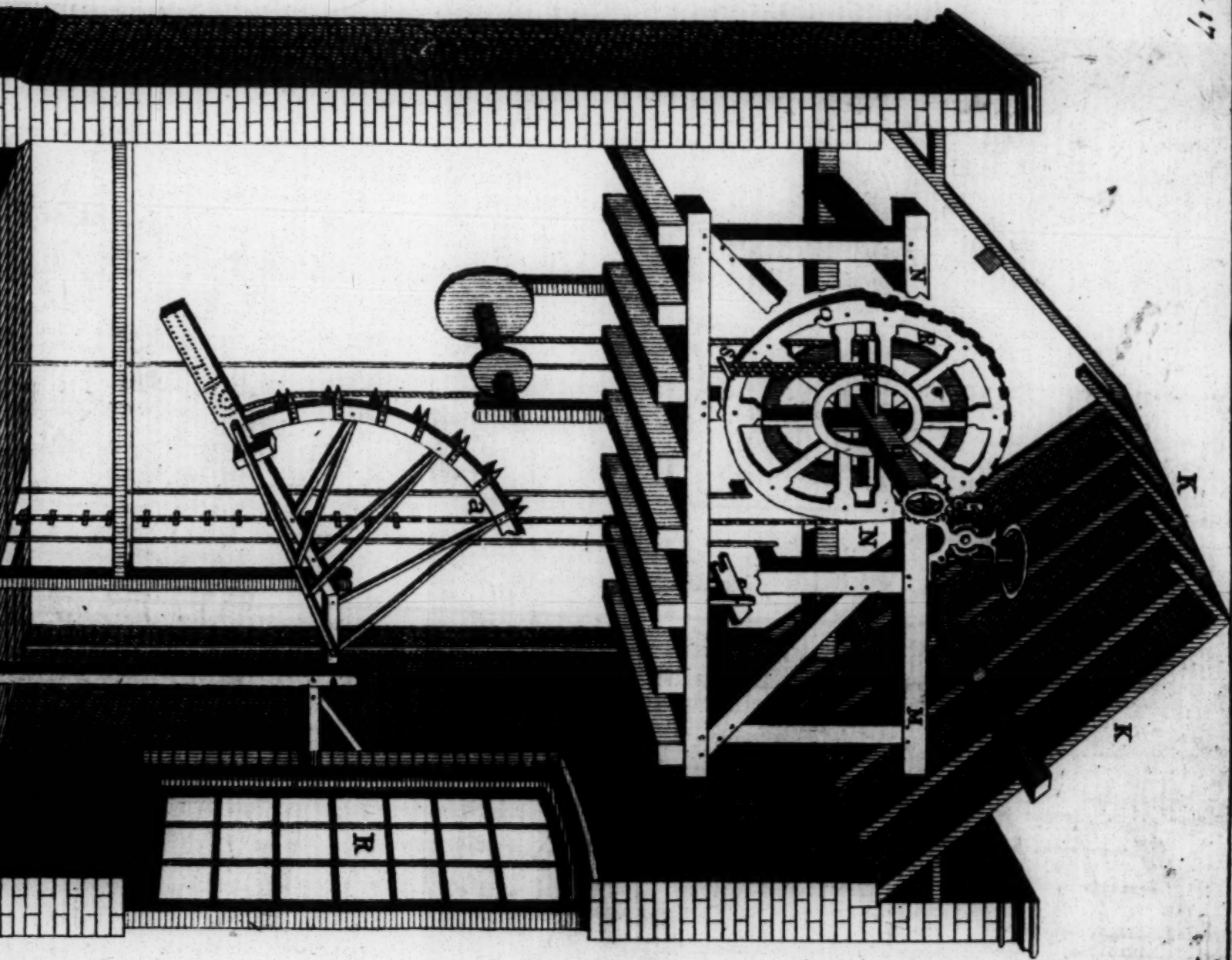


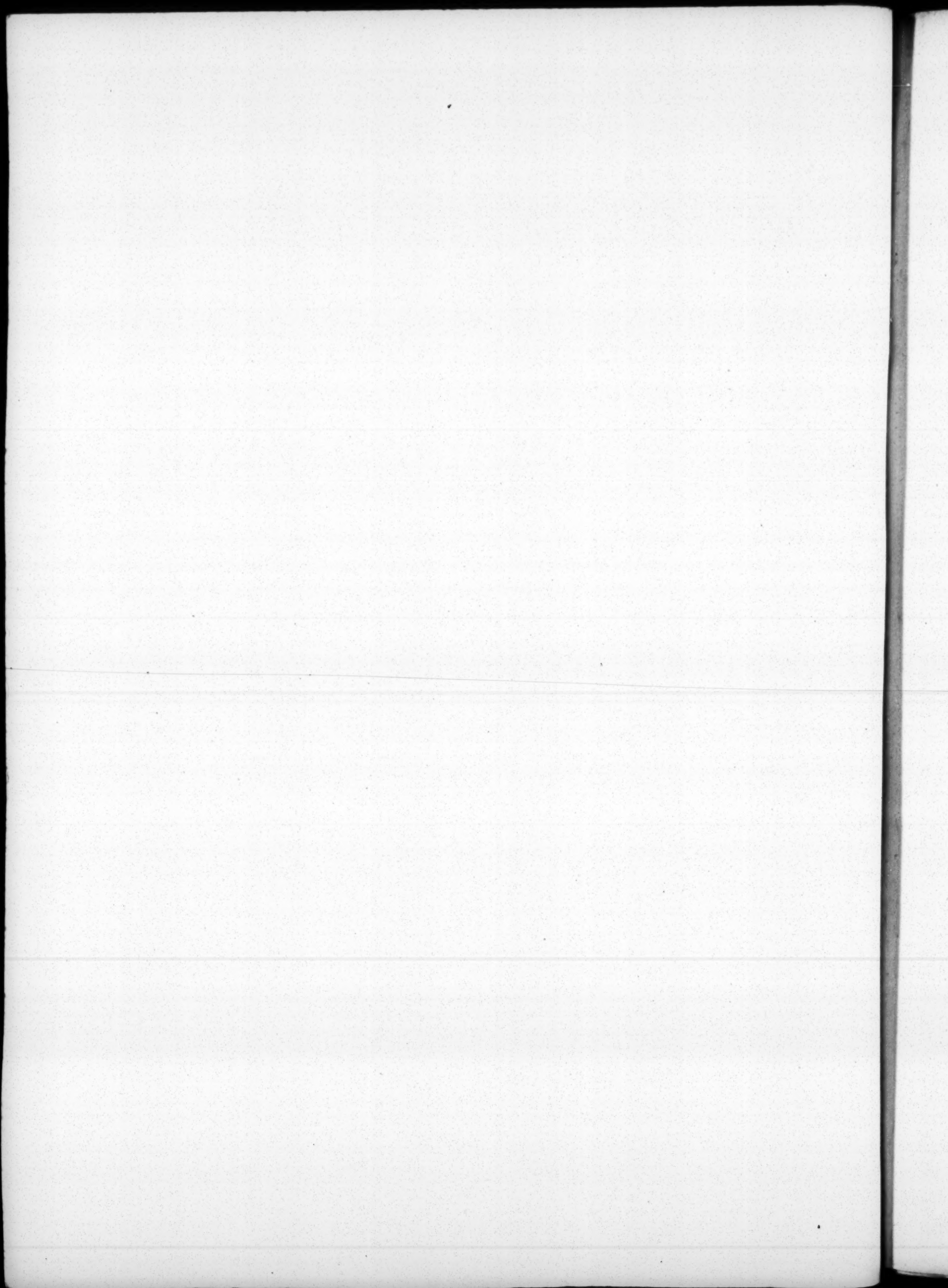


W. Dyer's *Multiplying Wheel Bucket Engine*

H. Dyer's *20 ft 20 sq ft*

H. Dyer's *20 ft 20 sq ft*





de Mineralium Fodinis, Fol. 145. seems to me to be the best of any that I ever saw in Machines of this Make: But as these Kinds of Engines are now intirely out of Use, and in as much as it is impossible the Pistons should descend well, without the Regulation, but of late invented, I pass on to the Regulator and Crank Work, compounded or mix'd as they are together, and without which neither of them can work well.

Now some of these Regulators are often plac'd horizontally on the Top of a Frame of Wood, or a Post such as are those of *Blenheim, London Bridge, &c.* and then the Thrust of the Water into the Pipes, is the same as in all perpendicular Pumps; but there are some others, the Thrust whereof is horizontal, and the Regulators perpendicular, as in the following *Plate 18. Fig. 1.* Some Engines there are, that besides the great Wheel which the Water drives, have also a little Wheel, that gives Motion to the Crank and Leaver Work; such is the Engine that belongs to the Merchants Water-works in *St. Martin's Lane*, the *London Bridge Machine, &c.* of all which Specimens will be found in the Course of this Treatise.

THE first Engine then that I shall produce, is one where the Regulators stand perpendicular, and where the Thrust is horizontal, being an old Engine that has been some Years erected in the County of *Surry*, and is, in my humble Opinion, as little liable to Friction, as any Engine already, or to be produc'd: And the Thrust being horizontal, the Water in the Pipes is subject to less Friction also than if the Thrust was perpendicular.

A A A (*Fig. 1. Plate 18.*) are the Frames of Wood wherein the Axle-tree, and Cranks B B run, C are the Floats of the Wheel, which dipping into, and being drove by the Water, gives Motion to the whole Wheel; the Pieces of Wood by D, E, F, are the Regulators fix'd into a Bottom Zill at O, O, O. I, H, G, the Iron Rods which go into the Pistons, and which drive the Water thro' the Pipes K, L, M, until the Water arrives into the Coffer N. From whence, by the Repetition of the Strokes of the Rods, and the continual Accession of more Water, it enters into the Pipe Q.

Fig. 2. Plate 18th, is a larger open Section of the Rods, Pipes, &c. beforemention'd, represented by *Fig. 3, 4, 5.* at which Places are Joints by which the Rods rise and fall (to prevent the Friction of the Pistons *a, a, a*, which are laid open in the dissected Pipes *b, b, b*) in the Coffer mark'd 10, there are little Valves, mark'd 6, 7, 8, which open and shut at the Approach or Retirement (if I may so express my self) of the Pistons *a, a, a*, to keep the Water from reverting back this Coffer, tho' drawn open here, to shew the
littl

little Valves before-mention'd, are cover'd, as are seen at N (in *Fig. 1. Plate 18.*) *Prædict.* and at No. 9. *Fig. 2.* is another Valve, to prevent the Water's returning back again, but to cause it, by a fresh Accession, to ascend the large Pipe thro' N^o 11.

THE Manner of the Rods being fix'd into the Pistons *a, a, a,* as mention'd in the last Paragraph, is seen in *Fig. 3. Plate 18.* where *d* is the Rod, and *a* the Joint; which Piston having a Notch (as from *b* to *e*) the Rod has the Liberty of rising or falling, as the Ascent or Descent of the Cranks and Regulators force it.

THIS Engine, I say, is subject to as little Friction, as any Engine of this Kind I have ever seen; for whoever will but be at the Pains of coming to see the Perpendicular Stroke Forcers we have on this Side the Water, at Mr. Kent's, the great Still-house at *Vauxhall*, will see how much those Engineers have endeavour'd to defend their Forcers against Friction. But of this more hereafter.

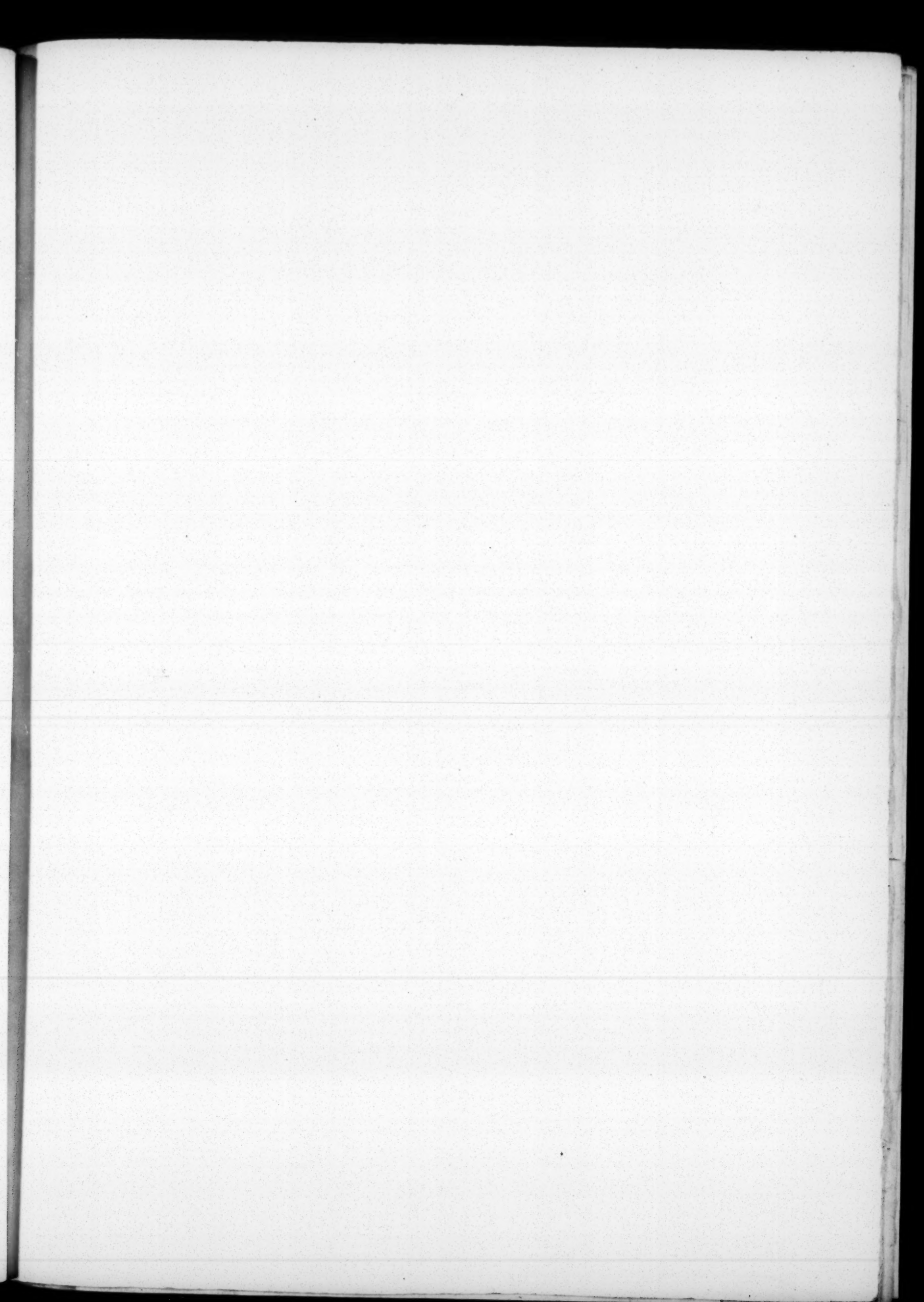


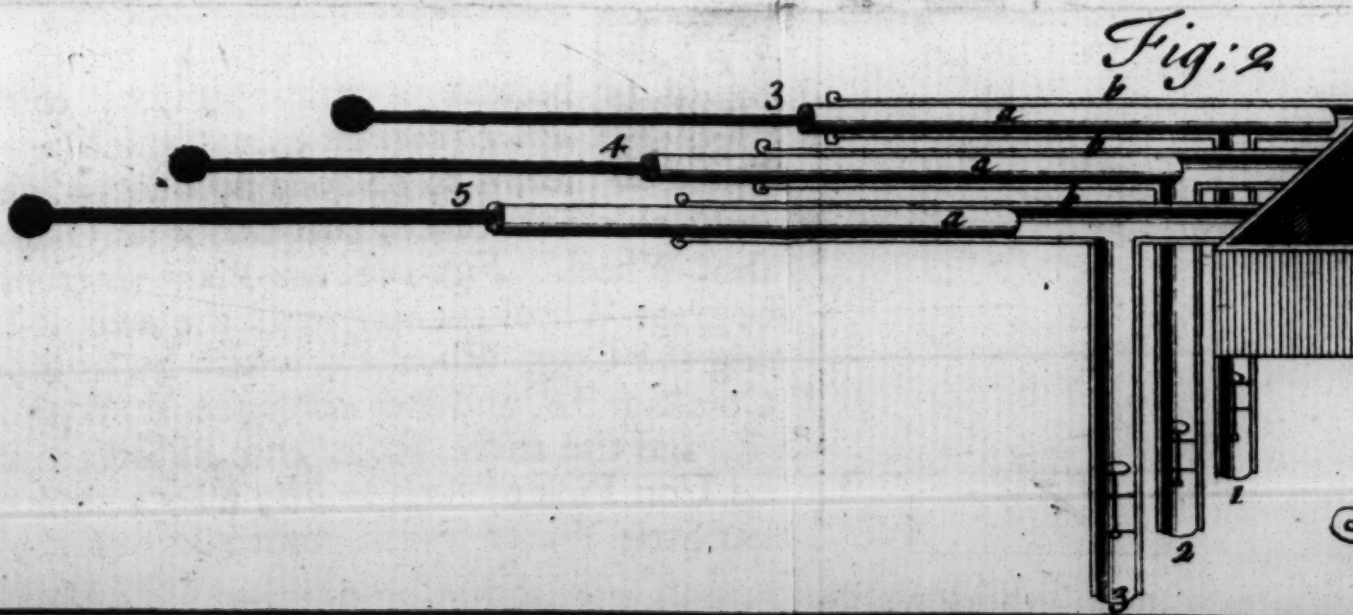
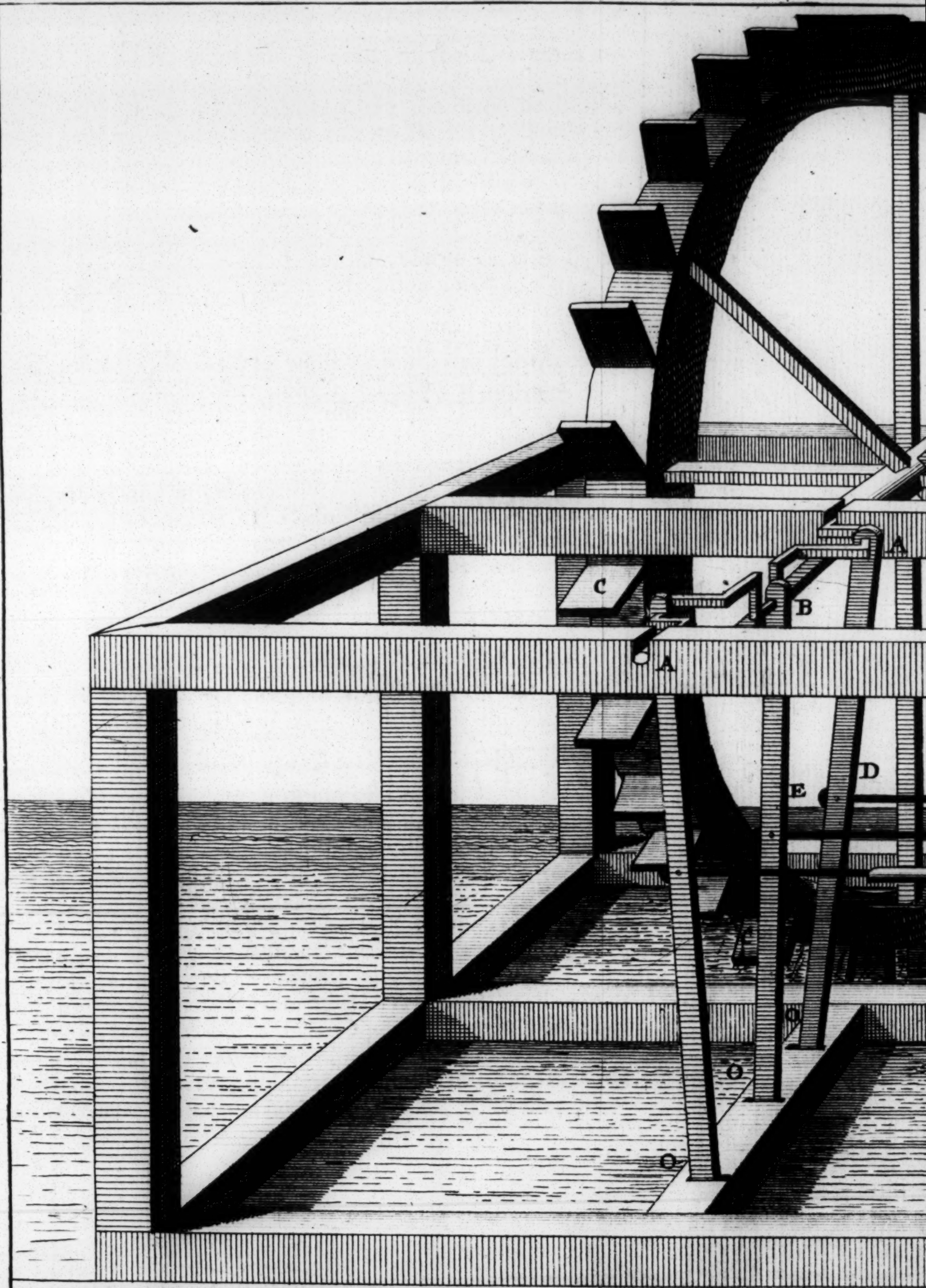
C H A P. XXVI.

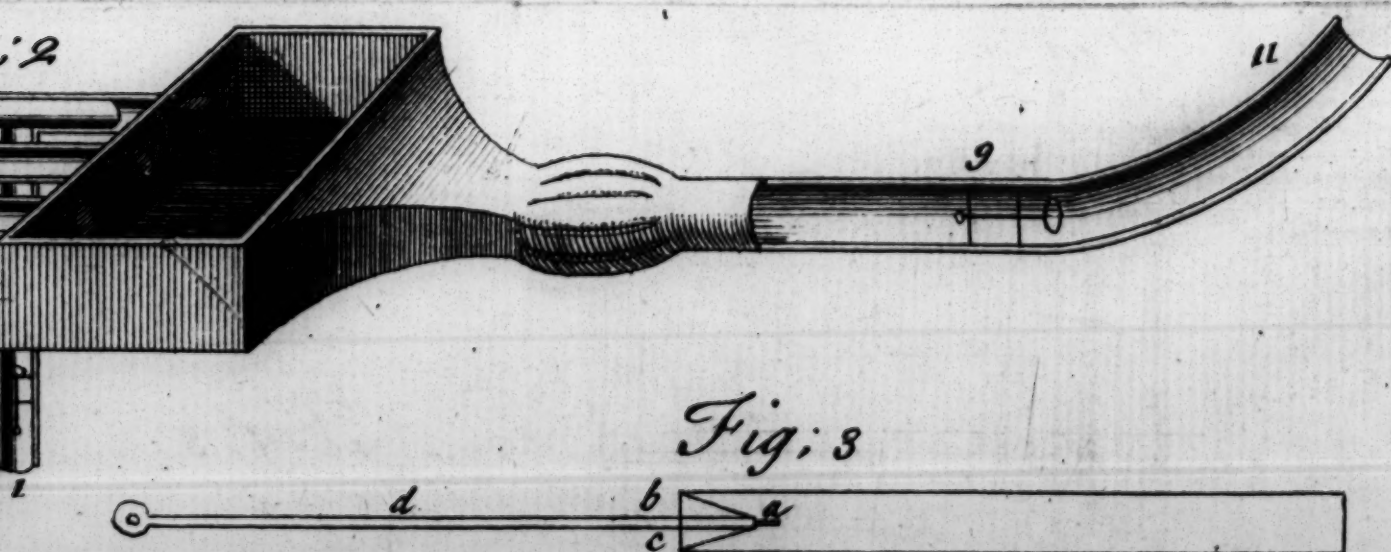
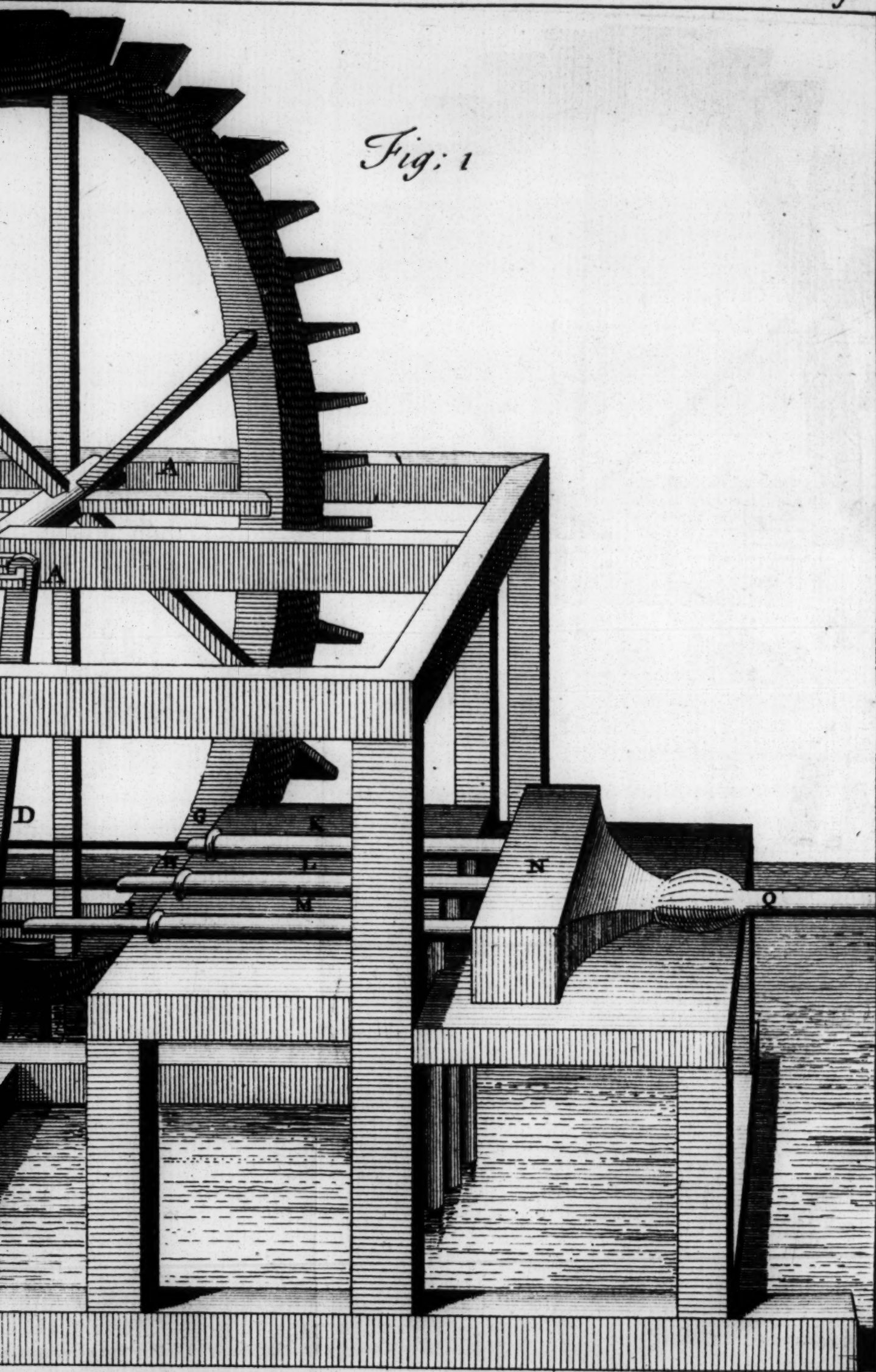
Of the Crank-Work, vibrating Leaver, and complicated or treble Wheel Engine for raising Water.

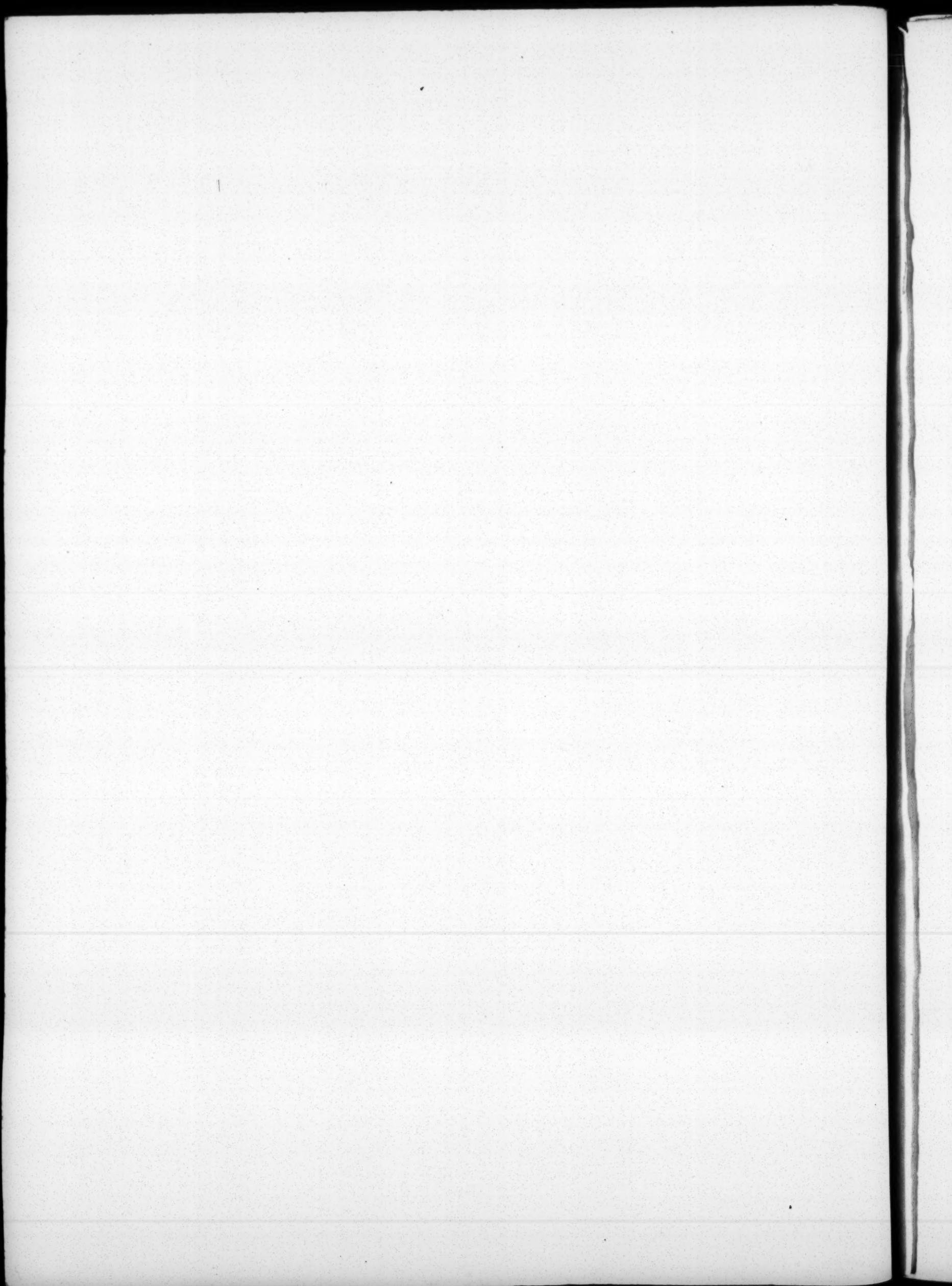


Plate 19. Page 320. is the Plan and Perspective of the Merchants Water-Work Engine at Tom's Coffee-house in St. Martin's Lane, which I insert in this Place, because it is preparatory to the Design of the *London Bridge* Engine; which by the Nature of the Work seems to be done by one and the same Hand, there being only this Difference, that this is an Over-shot, and that an Under-shot Wheel. *Fig. 1.* is the Plan, whereof A A is the Extremity of the great Wheel turning upon the Axis B B, C is the Spur Wheel turning the Cogg Wheel D, which by its Rotation gives Motion to the Cranks F F F, and they consequently to the Regulators or Leavers E E E, and the three Rods and Pistons mark'd *g g g*, which turn on the Iron Pins or Axis at *h h*; all which is effected by the Pressure of that little Water which comes out of the Pipe or Trough at I, *vid.*









vid. Fig. 2. Tab. prædict. where the Fixation of the Leavers is visibly seen to be in the Frame of Wood at K.

The Shape and Position of the Wheels are the same as in the *London Bridge* Engine, which follows, but the Floats or Boxes are set closer and nearer together, on Account of the small Quantity of Water which is to drive the Wheel; and here it is visible, what a small Quantity of Water will drive an Over-shot, over what will drive an Under-shot Wheel.

THERE is another Thing which I would observe in this Place, and that is as to the Number of Forcers which are needful in an Engine. Doubtless when these Kinds of Machines were first erected, there was but one Forcer, then the Number was augmented to two, and lately they are still encreas'd to three or four, tho' on Account of the Intermission of the Strokes, which, together with the Friction that is in the Pipes, and the Interruption and Interposition of the Air, us'd to be the Occasion that the Water would not (especially in great Lengths) issue out of the Ends of the Pipes regularly, but only alternately, and in Gulps.

WHATEVER the Proportion of these Pistons be, it is generally supposed by the best Workmen, that three Pistons are sufficient to maintain a constant Stream, tho' in very large Pipes of Conduct, such as those of *London Bridge* are; and where it is requir'd to raise a great Quantity of Water, they allow four Pistons to one Pipe of Conduct.

L L L are the Pistons, *m m m* the Barrels or Pipes where they work, and N N N the Representation of the Clacks or Valves.

N. B. In this Place I must remark a Mistake of the Engraver, who has in *Fig. 1. Plate 19.* shew'd the Cranks F F F, as if they work'd above the Leavers E E E, when in truth they work under them, as may be seen in *Fig. 2d.* and Leavers *m n o.*

THE next Crank Work Engine I shall produce, is the Plan and Perspective of one Part of *London Bridge*, which for Curiousness of Contrivance, the Length of Time it has went, without any other than very necessary Repairs, and the great Quantity of Water it throws up towards the Supply of that great Metropolis, may (Allowance being made for the Difference there is in the Number of Pistons that are in the one and the other) be well a Parallel, if not an Exceeding, to that great Engine of *Marley* itself, and which (as it has not as yet been produc'd in publick) will not, I humbly hope, be unacceptable to the judicious Reader, being, as I am told, the Work of one Mr. *Sorocold*, a very good Engineer, in the Reign of King Charles or King *James* the II^d. whether he had any Assistance from

320 *An Introduction to a General System*

Sir *Samuel Morland*, or any of the Great Men of those Times, I have not been able to learn.

A Description of the Plan, Vid. Plate 2c. Page 320.

A A is the Plan of the great Wheel.

B B is the main Axletree on which the Wheel is fram'd, and *l, l*, the Spindles, which from the Rotation or Movement of the Wheel give Motion to the Spur Wheels *c c*, and those by the Movement of that to the other 4 Wheels mark'd *x x x x*, which Wheels *x x x x* turn the Cranks *e e e e*, two of which at each Work are going up, whilst the other are going down; and this gives Motion to the Leavers *f f f f* on each Side the great Wheel, &c. and causes the Pistons *g g g g* at each Quarter to have an alternate Ascent and Descent in forcing up the Water thro' the Pipes *i i*, coming out at *h h h h*, and conveying it from thence to a proper *Reservoir* or *Reservoirs* for the furnishing the City.

THE Frames of Wood *k k*, &c. are for all the Wheels to turn upon, as *l l l l* before-mention'd, are the Iron Axis's, on which they turn; and here it is remarkable, that the two Wheels *c c*, whether by accidental or natural Contrivance of the Wheel, or by Design, is not material; but by Means of it, the Water is thrown over the Wheels *x x x x*, into the Axis or Spindle of the little Wheels, keeping them continually moist.

A Description of the Perspective of the London Bridge Engine, Plate 21. Page 320.

IN this Draught, at one Side View, is seen the Grand Wheel of the Engine, with the Regulators or Leavers; the first is mark'd A. A. the others B B. at each of which are the Regulators or Leavers, which from the Rotation of the Spur Wheels *c c*, give Motion to the Cog-Wheels D D D D, and they again to the Iron Rods, mark'd altogether E at both Ends. By this

F F F F, containing 4 Pistons at every Quarter, are all moving up and down alternately in the Pipes G G G G, the Suckets, which are a little below, still opening and shutting, as the working of the Engine requires.

AND with this I shall finish what I have to say as to the complicated treble Wheel Engine; I now proceed to the single Wheel Crank, and vibrating Leaver, as used by Mr. *Aldersea* in the Water Works of *Woodstock*, *Shrewsbury*, and other Places.

C H A P.

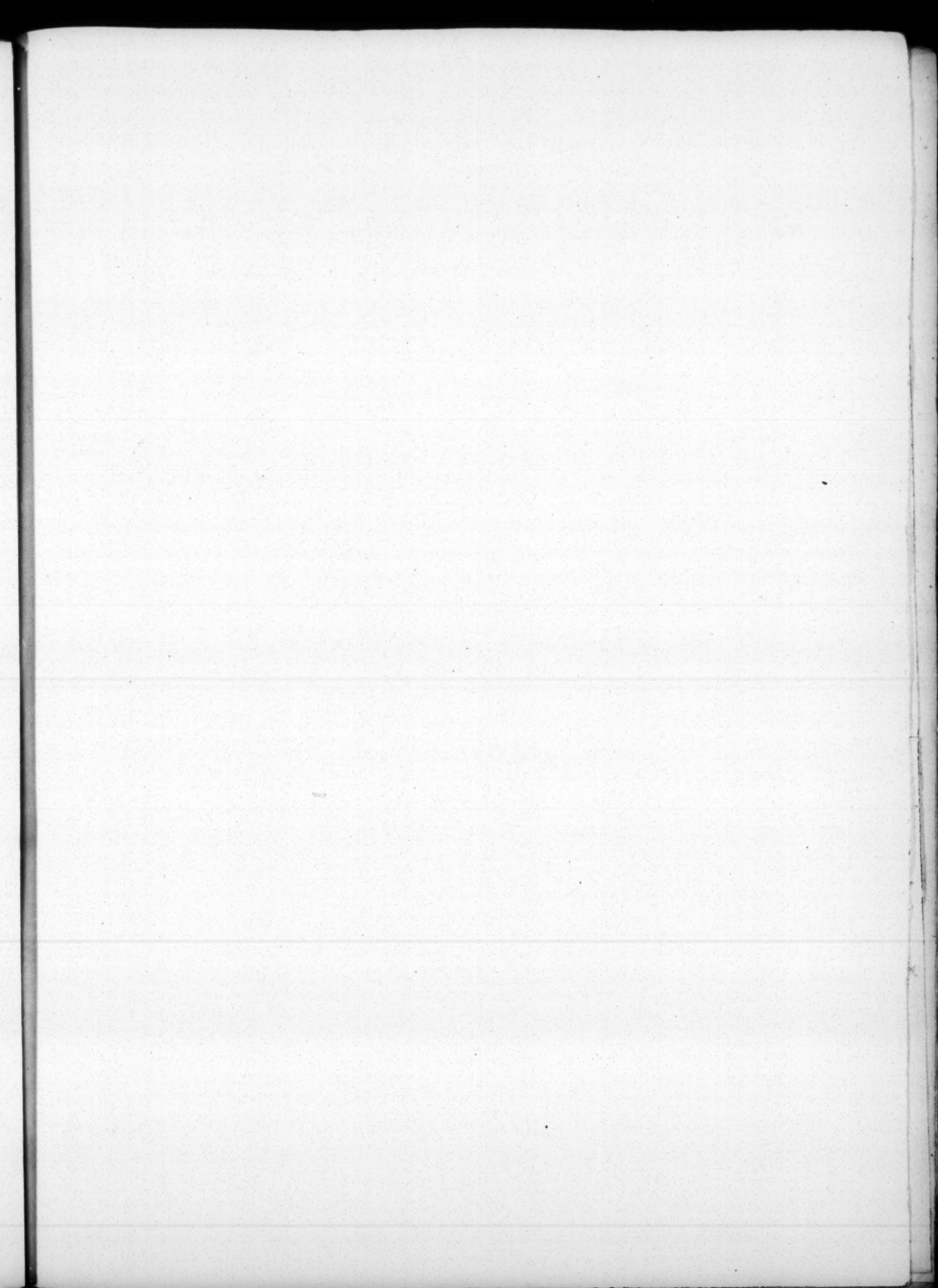
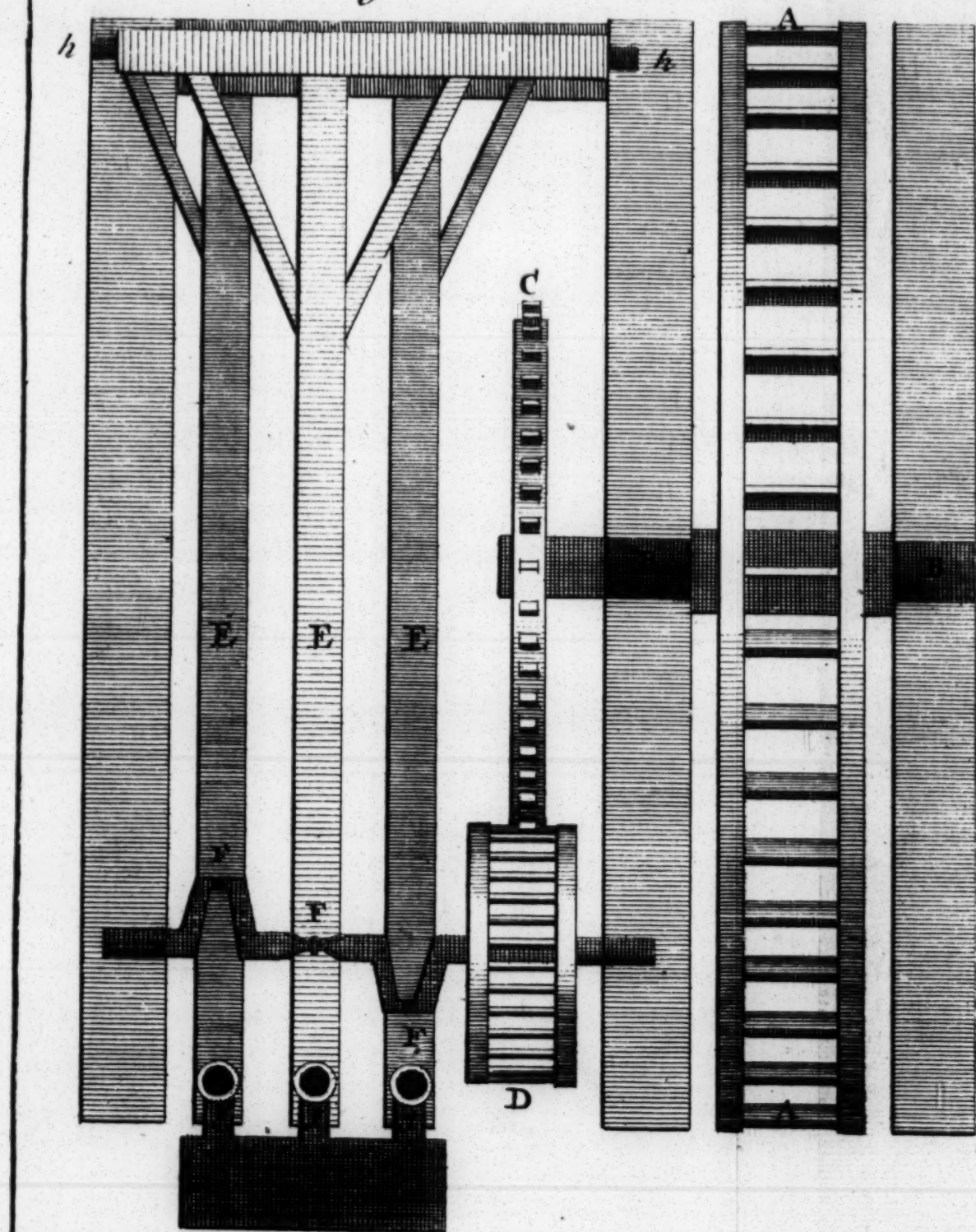
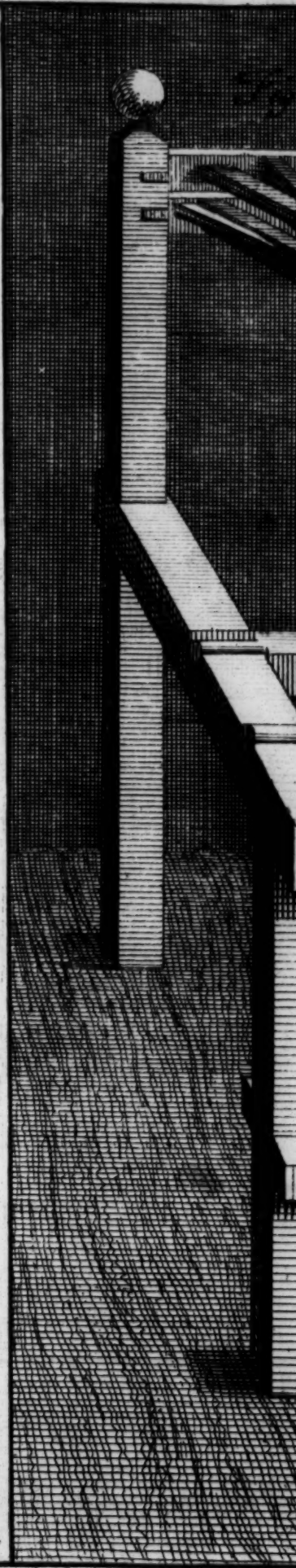
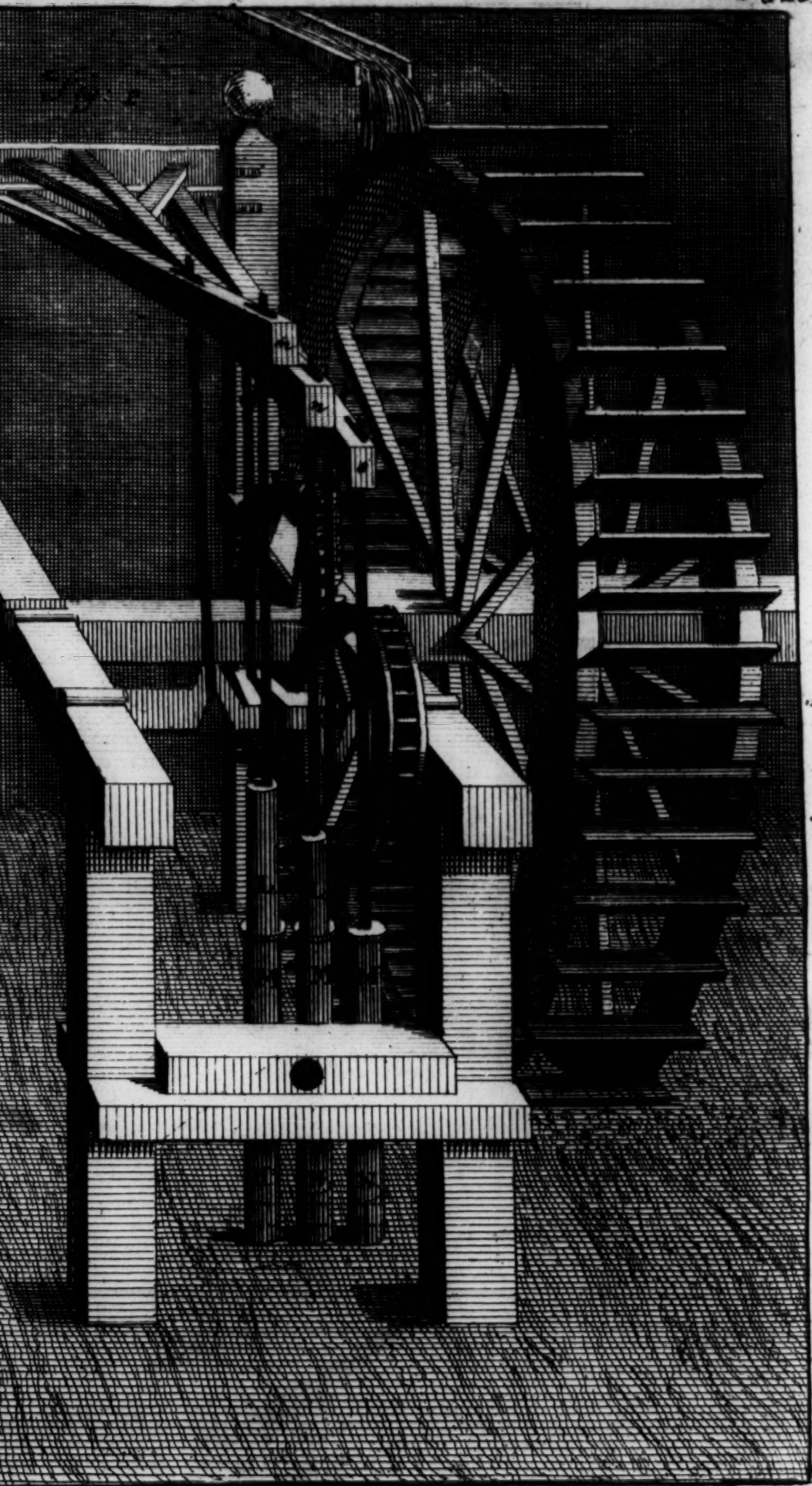


Fig. 1.

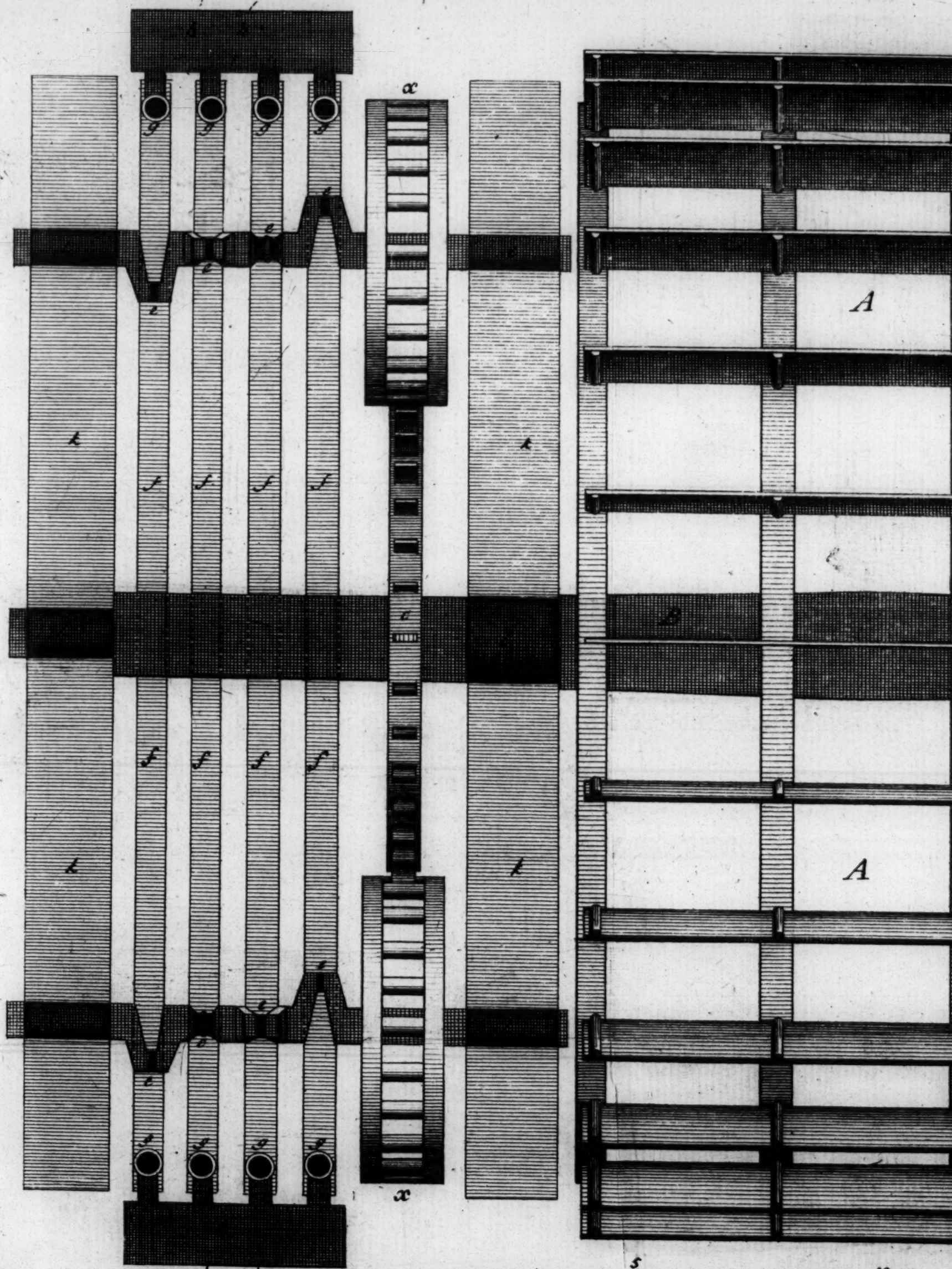


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A Scale of Feet

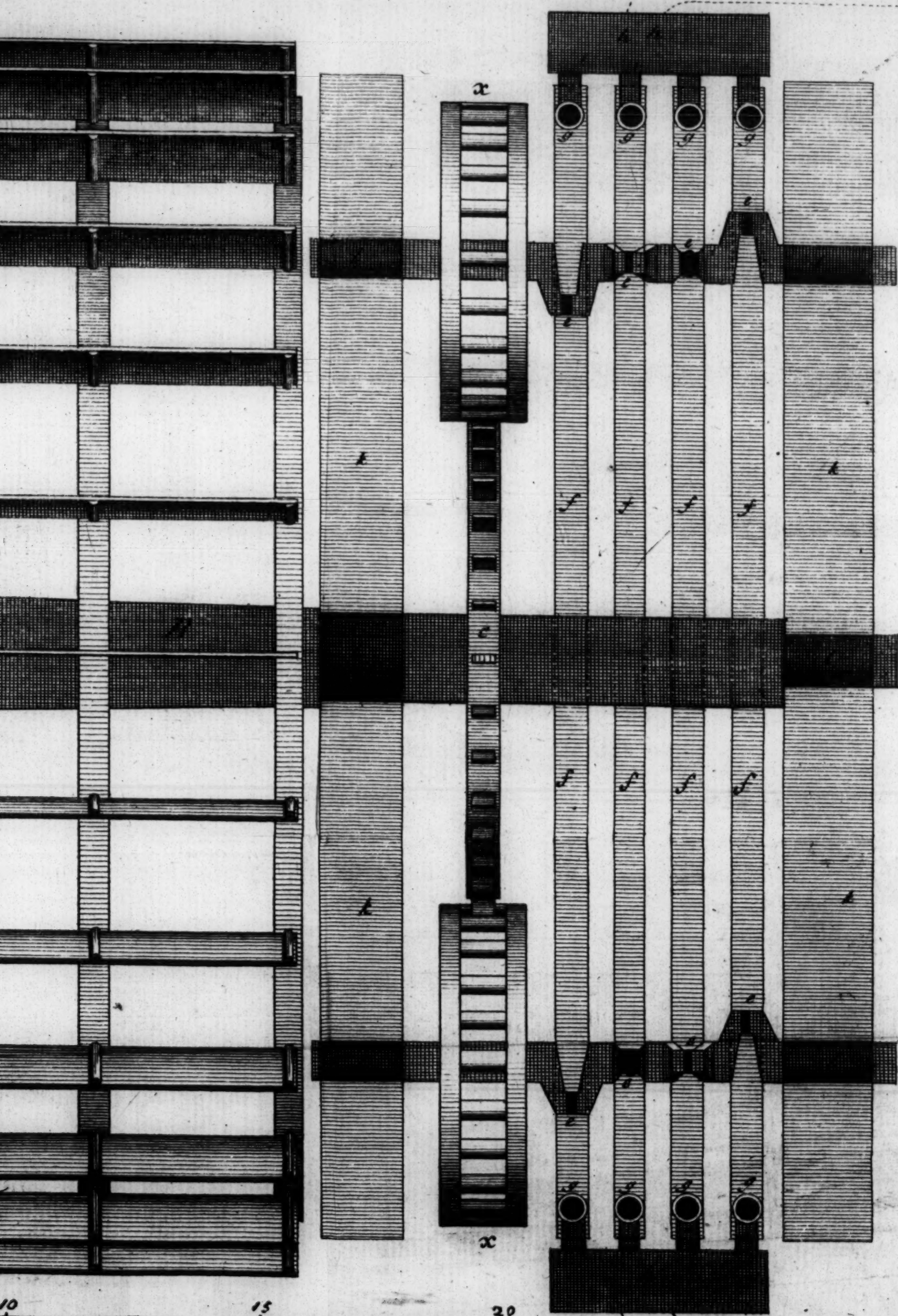




Toms Sculp



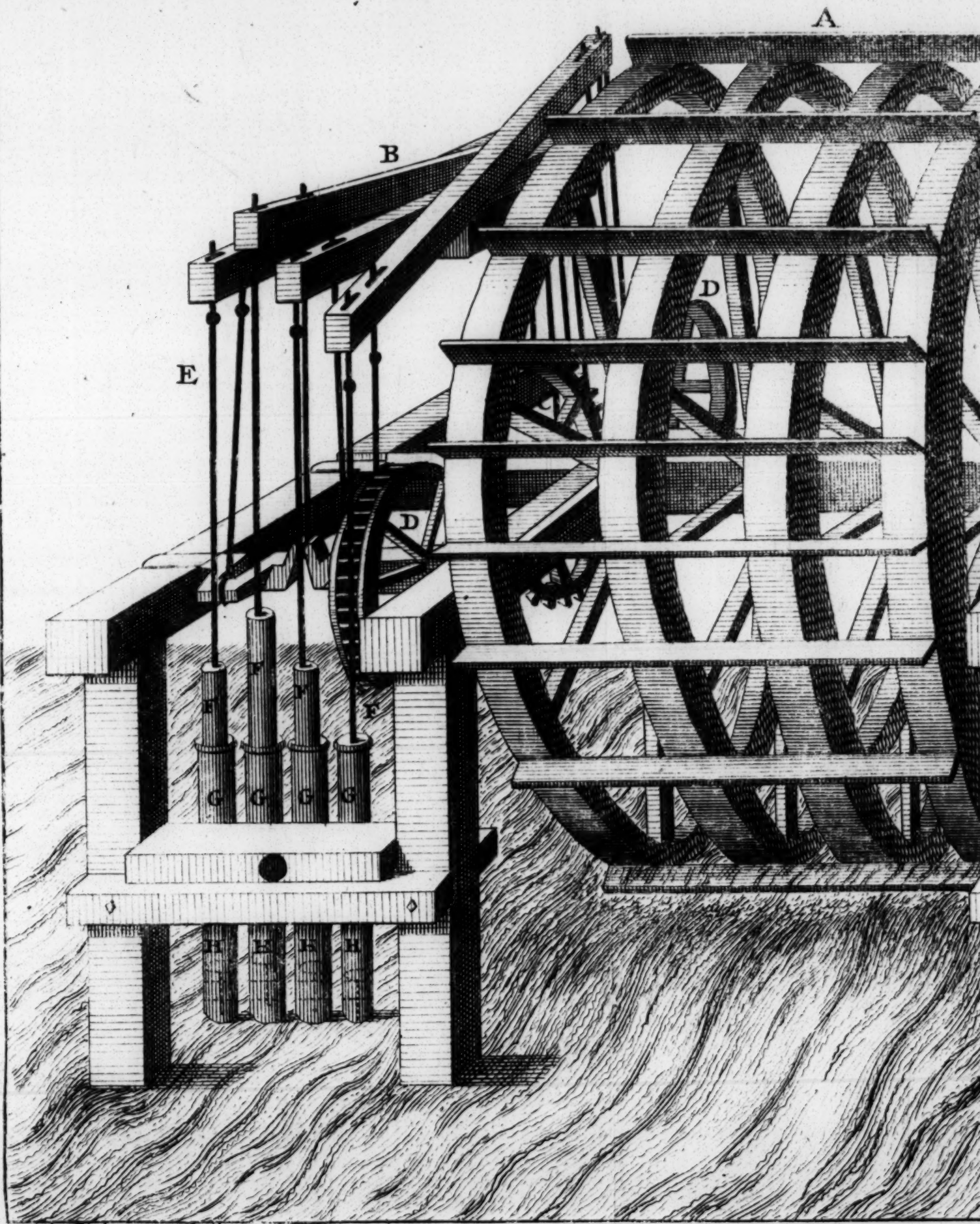
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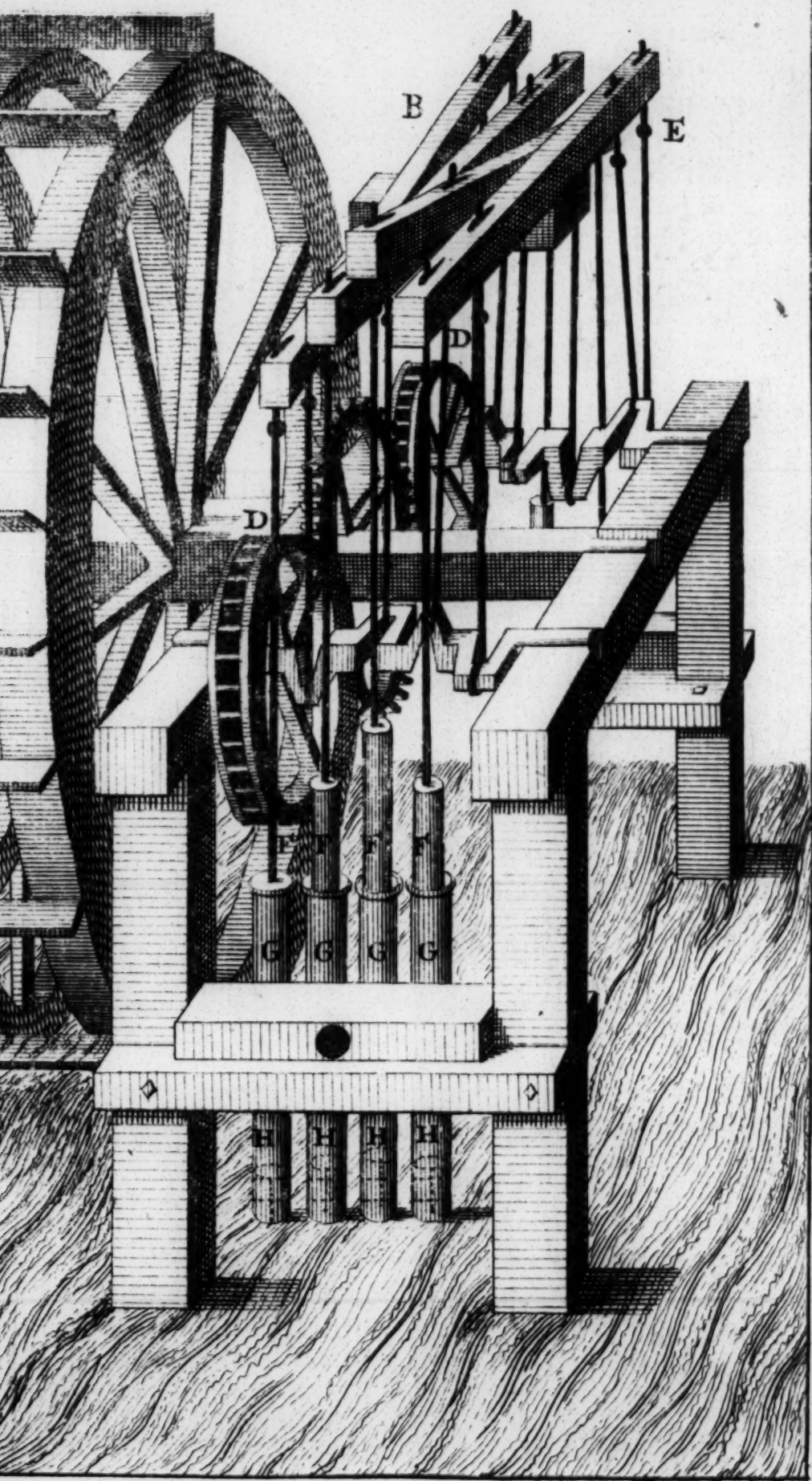
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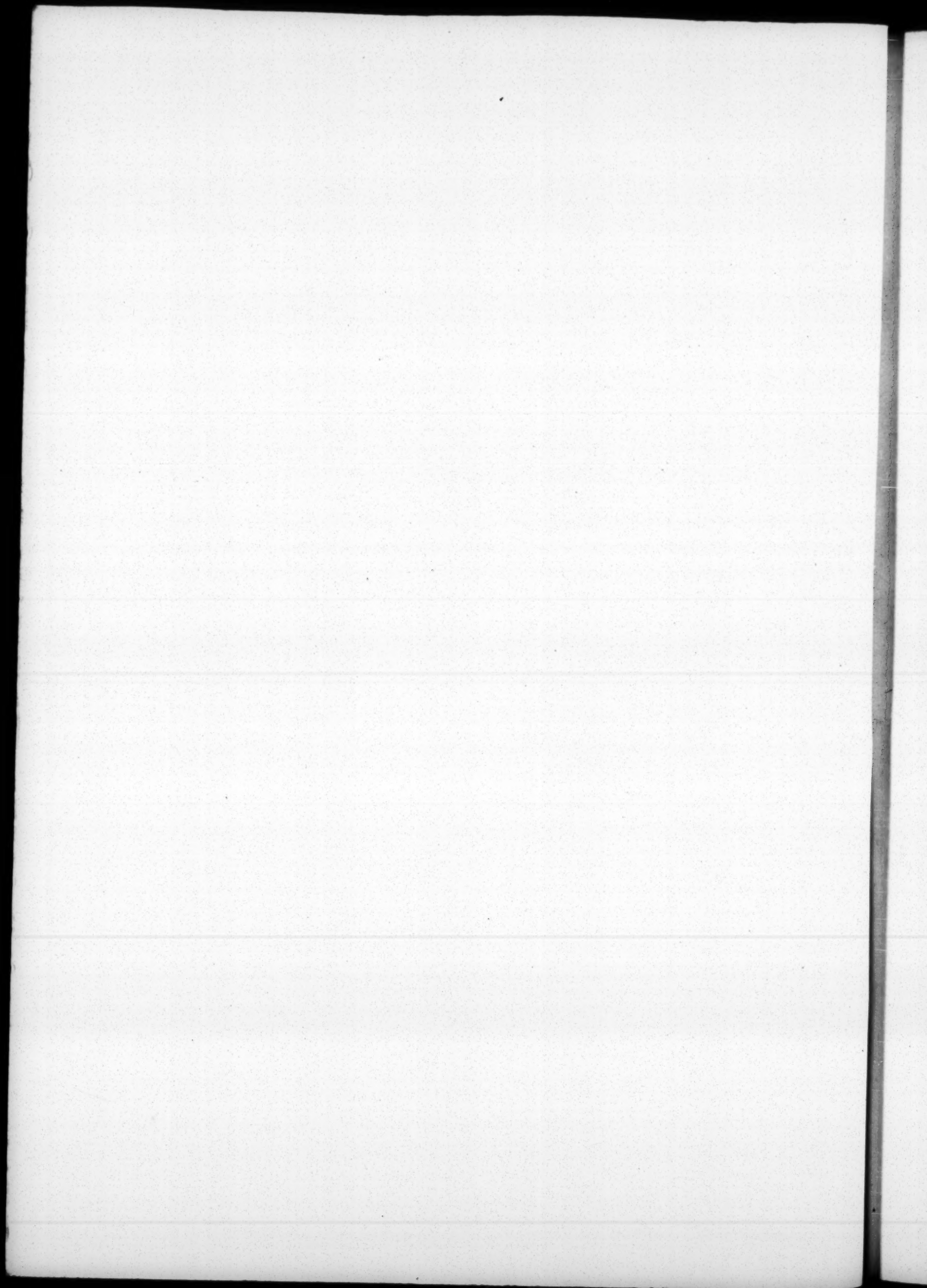
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Will. Haffpenny Delin.



Tom. Sculp.





C H A P. XXVII.

*Of the Vibrating Leaver and Crank-Work Engine, with
a single Wheel only, to give them Motion.*



THE vibrating Leaver and Crank-Work Engine, with a Spur and Cog-Wheel, such as is at the Merchants Water-Works, and at *London Bridge*, being thus accounted for and explain'd, the next Engine to be produc'd, is one of those invented by Mr. *Aldersea*, who, though a Dry-Salter by Profession, was at that Time allow'd to be so curious an Engineer, that he was, amongst other Works of that Kind, employ'd by his Grace the Duke of *Marlborough*, at his fine Seat of *Woodstock*, the Plan and Perspective of which Machine follows in one of the next Plates, which I produce, in as much as it has given Rise to several other curious Engines of this Kind.

THIS Ingenious Gentleman, considering the great Friction that was in the Multiplication of the Spur and Cog-Wheel; which tho' useful in the raising of great Weights, where there was a moving Force of equal Strength apply'd to it; yet in Engines for raising Water, especially where the Stream which was to play it, should not be very strong, the Friction of the Wheels was so great, as to retard rather, than accelerate their Motion; this put him upon taking away the Spur and Cog-Wheel, and depending entirely on the main Wheel for the turning the Cranks, and by poising the Regulators and Leavers in such a Manner, as that the Work might go with a less Shock than it us'd otherwise to go: How well he has succeeded, let any one that ever saw that little Engine of *Blenheim*, (supply'd as it is by a very small Stream of Water) determine: The Description of which now follows, *viz. Plate 22. Page 324.*
A represents the Stream of Water that plays the Engine.

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B B B the Thorough or Trough, which conveys the Water upon the Top of the Wheel C C into several Boxes, made somewhat like a *Roman* Figure of V turn'd a little sloping, which having push'd on the said Wheel, is delivered into a Waste or Tail Water D D D, which runs thro' one of the small Arches or Bridge next to *Rosamond's* Bower.

THERE are but three Cranks on a Side, and the having of double Works (*viz.* three of a Side) is that in Case any of the Cranks in one Side are broke, the other may be us'd, which is either fastned to, or loosen'd from the Wheel by a Collar pull'd off or put on at *f f*.

THE little Letters *aaa aaa*, are the Keys to the vibrating Leavers, which rest on the Fulcrum or Prop on which they move by the Rotation of the Wheel C C; which turning the Cranks mark'd Q Q Q Q Q Q, move the Leavers C C C, &c.

THE Pistons which are thereby agitated, and put into Motion, and which are well known by the Marks O O O O O O on each End, &c. forces the Water out of the Coffer *rrr, rrr*, situate as they are at each End, from whence pass Pipes, which are in the Plan unseen, under one of the Stair-Cases S S, up thro' the Bridge, to the Cistern on the Top of the Offices.

T T T T are Passages round, and in the Front of the Engine, to view it and come at it, to keep it clean from the upper Part T₂ T₂, is as high as the Top of the Wheel, which is seven Foot and an half Diameter, and is play'd by as little Water as any Engine of this Kind can be; the little Marks *oooooooo*, &c. are the Foundations of a Grillade of Iron Work made to keep any Body that ascends the Stairs, and goes to pull up the Sluice at B from falling upon the Engine; and somewhere in the Coffers near Z, are Boy Cocks, being hollow Balls of Copper, which rise or fall, according as the Water in the Coffers *rrr*, &c. do; so that when the Coffers are Brim-full, and like to run over, those Boy Cocks shut close, and admit of no more Water to make a Wetness or Dirt in the Engine House.

THERE are Pipes which come from the Stream A, thro' the Wall by B, which supply the said Coffers with all common Water: But there was a Design, whether perfected or no, I am not certain, to fill one of the Coffers, (*viz.*) that next *x*, with fine Water from *Rosamond's* Well; which lies within about 100 Yards of that Place.

I have been the more particular in my Account of this Engine, having had the Pleasure of conversing much with Mr. *Aldersea* the
curi-

curious Contriver, and should be sorry, if from the Length of Time, and the faint Memorandums I now have of this curious Piece, it be not the most perfect; tho' I think, and am pretty sure, that there is nothing very material omitted in it: And in Behalf of the Engine, it may be truly said, tho' perhaps there have been several Engineers, who have since improv'd upon it; yet, as it is the easiest Piece, going (comparatively speaking) with as little Noise as a Watch or Clock; so Mr. *Aldersea* (tho' he has long left Art behind him) deserves the just Applause of all honest ingenious Men.

THERE is one Thing which I see liable to an Objection, which is that the Fulcrum or Prop, which is noted by the Marks *a a a*, is not in the Middle of the Leavers, which, if my Memorandums fail me not, is Fact in the Execution of it; but if it be an Error, it is such a one as I could not, during the Hurry of Business, and little Time, I have had, correct; which is all I have to add in this Place, only that Y Y Y Y, &c. is the Foundation of the Walls encompassing the Work.

A Description of the new Part of the Chelsea Water-Work Engine.
Vide Plate 23. Page 324.

I omit the old Work, because it is so near the Model of the Spur and Cog-Wheel at *London Bridge*, and confine my self to one Part only of the New; which was last erected, being, as it is said, the Invention of the late ingenious Mr. *Rowley*, and others, and which is made nearly resembling the little Model, which stands in the House first erected, only in that there are five Pistons, and in the erected Work but four.

THAT the Engineers (whoever they were) proceeded upon the same Model as Mr. *Aldersea* did at *Blenheim*, confining themselves to a single Wheel and Cranks only, I need but just repeat; and that this new way of working goes easier, and is better at low Water than the old, Experience teaches; for tho' by the Number of Wheels, and the Nature of complicated Work, the old Work goes quicker at high Water than the other, the Rotation of the great Wheel moving the Spur and Cog-Wheel with great Celerity; yet the single Wheel, when unloaded of the Weight of the Tail Water, goes much quicker and easier than the other, which is much impeded by the Friction of one Wheel against another; an Obstruction so great, that were not the Quantity and Pressure of the Water almost invincible, it would not have its due Effect.

NEVERTHELESS, tho' a great many Arguments may be produc'd for the new way of working, where the Tail of the Wheel is clear'd by a quick Passage of the Water from its Tail; yet I can't but say, that for an Engine continually working in the Water, as that of *London Bridge* does, the Addition of the Spur and Cog-Wheel is the Best for the Reasons before hinted at. This being premis'd, let the Description of the Engine follow.

A, *Fig. 1. Plate 23.* is the Trough from which the Water, by the pulling up a Sluice there, falls under the Passage or Gang-way on the Wheel B B B, the waste Water goes off at C into the River *Thames*, the Diameter of the Wheel is 24 Foot, and about 5 or 6 Foot wide, and the Surface, or general Height of the Water in the largest Mill Pond or Ponds, which the industrious Undertakers have in all the low Meadows so judiciously made—, is eight Foot; which Water falling on the Bottom of the Wheel at B, N^o. 1. gives such a Thrust, as must, comparatively speaking, move a Mountain. How much that Weight is, has been already demonstrated.

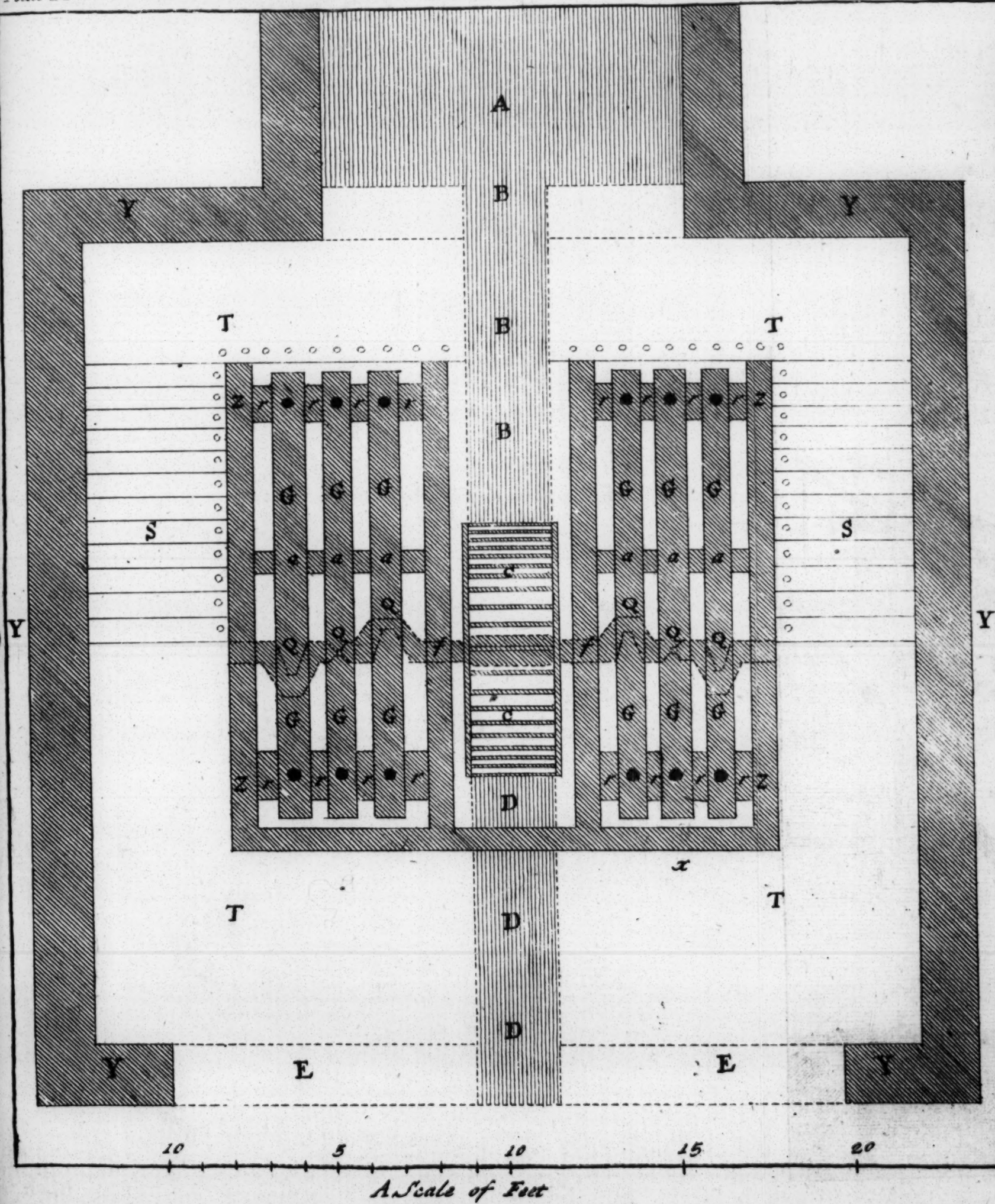
FOR the farther Demonstration of this Engine, let it be added, that the Leavers *aaaa*, &c. are about 23 Foot in Length, which by the Movement of the Cranks *bbbb*, have a vibrating Motion turn'd as they are on the Fulcrum or Props at *oooo*; *cccc* are the Places where the four Pistons which force the Water up, are fix'd, which being fix'd into those largest Places, and have a Joint a little below it in the Rod, gives Way, and prevents that Friction that would otherwise be in the Barrels below.

NEAR to *kkkk*, &c. at each End, are the two Engine Trees, which having Pipes that come sloping to them from the Coffers or Boxes where the Pistons work, the Water takes its Course into the Pipe *ll*, thro' which it is flung up thro' the main Pipe, into any Place assign'd.

N N are passages or Gang-ways to go round the Engine, to mend it, to make Fires to keep it from freezing, and the like.

THE Perspective, *Fig. 2d. Tab. Prædict.* is so plain, that it needs no further Explanation than its own View, only at *aaaa* are the Joints in the Rods, which are made to give Play to these, and were there little Rowls or Wheels in the Channels or Mortises above, it would still help to prevent the Friction that is almost unavoidable in the Fall of the Pistons, I say, almost unavoidable; for as the Regulators must of Necessity move upon one Axis or Center at *oooo*, their Vibration must be circular, and their Fall not exactly perpendicular.

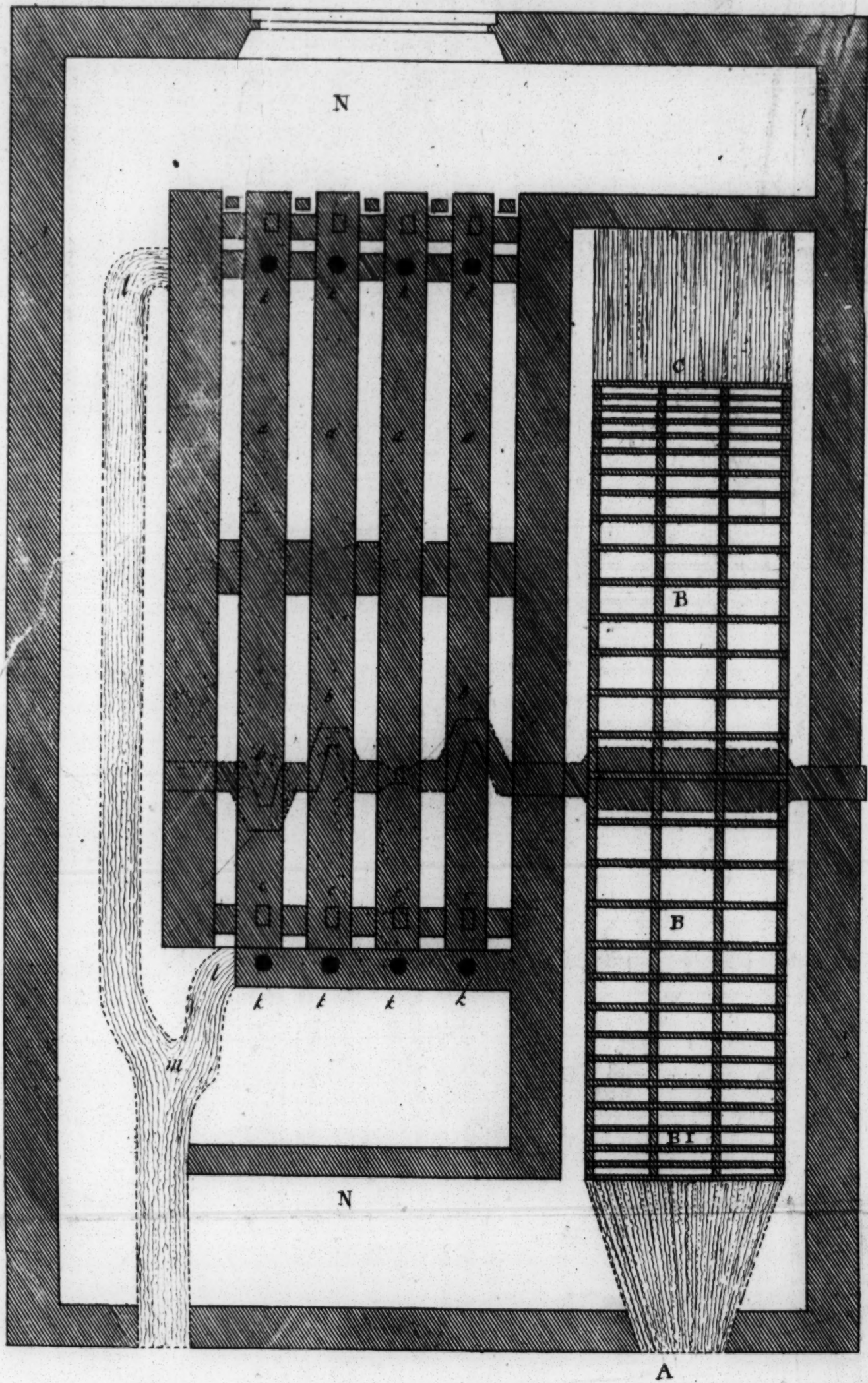






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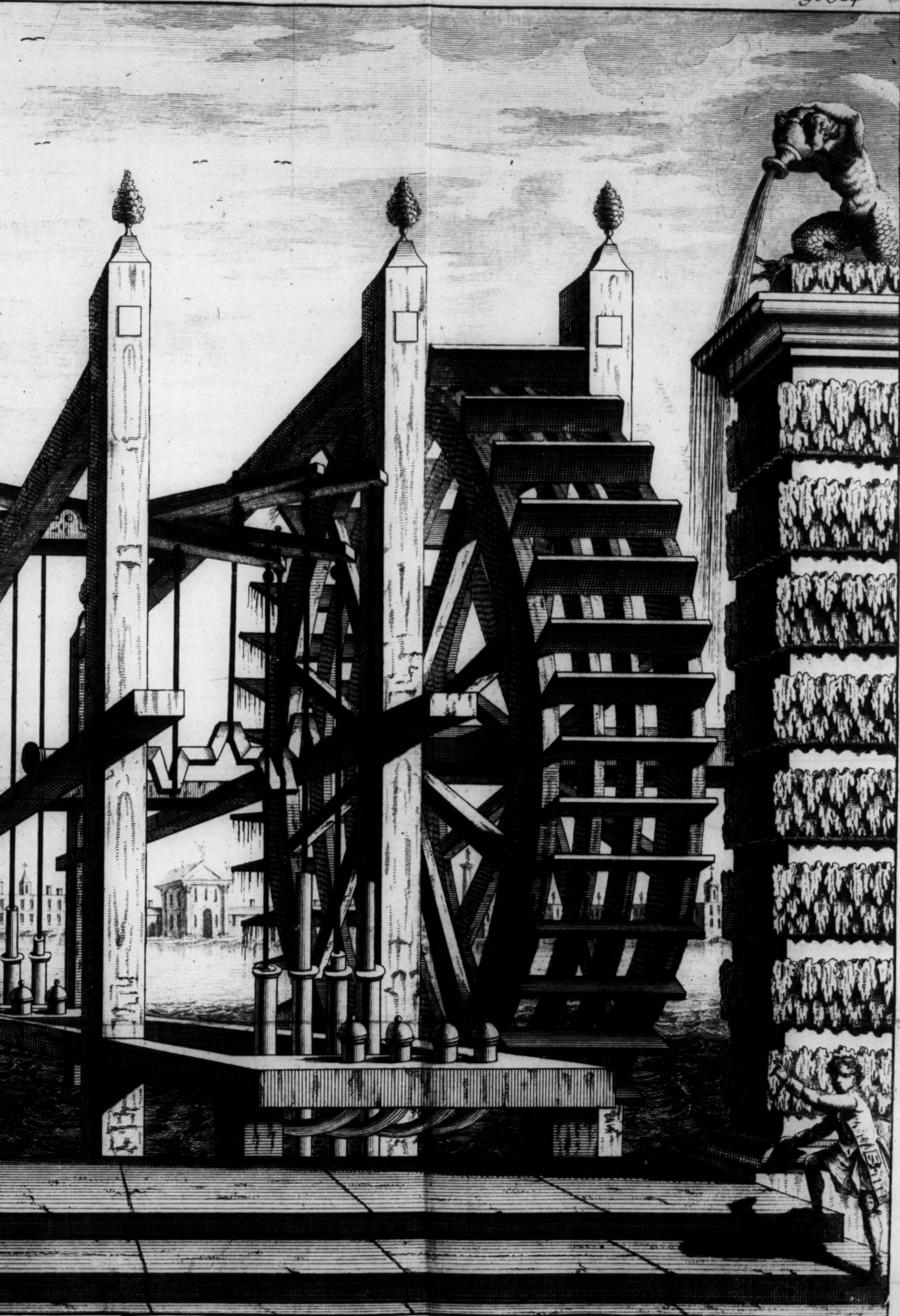
Toms Sculp.



10 5 10 15 20
A Scale of Feet



J. Norwott Delin.





C H A P. XXVIII.

Of the Engine for raising Water by Fire.

AMONGST the several Engines which have been contriv'd for the raising of Water for the Supply of Houses and Gardens, none has been more justly surprising, than that for the raising of Water by Fire; the particular Contrivance, and sole Invention of a Gentleman, with whom I had the Honour long since to be well acquainted; I mean, the ingenious Captain *Savery*, sometime since deceased, but then a most noted Engineer, and one of the Commissioners of the Sick and Wounded.

THIS Gentleman's Thoughts (as appears by a Preface of his to a little Book entituled, *The Miner's Friend*) were always imployed in Hydrostaticks or Hydraulicks, or in the Improvement of Water-Works; and the first Hint from which it is said he took this Engine, was from a Tobacco Pipe, which he immers'd to wash or cool it, as is sometimes done; he discover'd by the Rarefaction of the Air in the Tube by the Heat or Steam of the Water, and the Gravitation or Impulse of the exterior Air, that the Water was made to spring thro' the Tube of the Pipe in a wonderful surprising Manner; tho' others say, that the learned Marquis of *Worcester* in his *Century of Inventions* (which Book I have not seen) see Page 68. gave the first Hint for this raising Water by Fire.

IT was a considerable Time before this curious Person, who has been so great an Honour to his Country, could (as he himself tells us) bring this his Design to Perfection, on Account of the Awkwardness of the Workmen, who were necessarily to be imploy'd in the Affair; but at last he conquer'd all Difficulties, and procur'd a Recommendation of it from the Royal Society in *Transac.* N^o. 252. and soon after, a Patent from the Crown, for the sole making this Engine; and I have heard him say my self, that the very first Time he play'd, it was in a Potter's House at *Lambeth*, where tho' it was

a small Engine, yet it forc'd its Way thro' the Roof, and struck up the Tiles in a Manner that surpris'd all the Spectators.

ABOUT the Year 1699, he wrote a small Pamphlet or Treatise concerning this Engine which I have just now mention'd, wherein he has exhibited a Draught of it, (which, with its Improvements, is to be found in the next Plate) as also, a particular Description of its Uses, which will follow in this Chapter: But as that consisted of a double Receiver, and a great many Particulars not so easy for a Learner at first Sight to understand, I have first of all inserted that Draught, with the Account thereof, which Mr. *Bradley* in his *New Improvements of Planting and Gardening* has given us of that at *Cambden House*, it being an Engine of Mr. *Savery's* own Invention, and which is the plainest and best proportion'd of any that I have seen; and after that, I shall give the Author's own Drawings, and the Account by himself publish'd of his double Receiver, with the Improvements thereunto made, which are undoubtedly necessary in great Heights, and where great Quantities of Water are to be rais'd.

A Description of the Fire Engine, Fig. 1. Plate 24.

A The Fire

B The Boiler; a Copper Vessel of a spherical Figure, in which the Water is boiled and evaporated into Steam, which passes thro'

C The Regulator, which opens to let it into

D the Steam Pipe (of Copper) through which it descends into

E the Receiver, which is a Vessel of Copper also, that at first setting to Work, is full of Air, which the Steam will discharge thorough

F the Engine Tree, and up the Clack at

K (the Plug of the said Clack to come at and repair the same, if need be) and so the Air ascends in

L the Force Pipe——, after E is void of Air, which is found by its being hot all over, then stop the Steam at

C and throw a little cold Water on at E, and the sucking Clack will open at

I (which is the Plug of the said Clack) and fill E with *Water*, which will ascend thorough

G the Sucking Pipe from

H the Pond, Well, or River.

THIS being done, proceed to raise your Water, (*viz.*)

First, TURN C to let the Steam pass from the Boiler into E, and it will force the Water therein thorough F by K up L; which Water

can't

can't descend, because of the Clack at I. When E is thus emptied, which may easily be perceived, by its being hot, as before, turn C, and confine your Steam in B; then open the Cock M, which will let a little cold Water into E, and that by condensing the Steam in E, will cause the Water to ascend immediately from H, and replenish E.

THEN turn C, to let the Steam into E, and it will Force the Water out of it up L, into a Cistern at O, placed at the Top to receive it. Then confine your Steam at C, as before, and turn M for the space of a Second or two of Time, and E will be refill'd, which may again be discharg'd up L, as before: So that this Work may be continued as long as you please, if you keep the Water in B.

IF you turn the Cock N, and then only Steam comes out of it, (without hot Water) the Boiler must be replenish'd with fresh Water; but our Boiler of Water will last a long while.

WHEN you have rais'd Water enough, and you design to leave off working the Engine, take away all the Fire from under the Boiler, and open the Lock N to let out the Steam, which would otherwise (was it to remain confin'd) perhaps burst the Engine.

IT must be noted, that this Engine is but a small one, in Comparison of many others of this Kind, that are made for Coal Works; but this is sufficient for any reasonable Family, and other Uses required for it in watering all middling Gardens.

THE Proportion of the several Parts of it as it now stands at *Cambden House*, take from Mr. *Bradley*, as follows.

THE Pipe from the Surface of the Water, to the Engine Tree F, is 16 Foot, which is the Length it sucks the Water, or rather through which the Water is drove by the outward Force of the Atmosphere; but as the aforesaid ingenious Gentleman observes, might be made to draw or force Water (according to the Laws of Hydrostaticks) 28 Foot very well; but according to the Rules before mentioned, to 33 or 34 Foot; however, in Attempts of this Kind, it is better to be under your Mark, than above it.

BUT to proceed from the Engine Tree F, up to the great Cistern which receives the Water, is 42 Foot (but as Mr. *Bradley* thinks) might be 100 Foot high, if such a Quantity of Steam be allow'd as is proportionable to the Length of the Pipe.

THE Diameter of the Bore, as well of the sucking Pipe G, as of the force Pipe L, is three Inches; and of the Steam Pipe D about an Inch.

THE Receiver holds 13 Gallons of Water, and the Boiler three times that Quantity.

WHEN

WHEN this Engine begins to work, you may raise four of the Receivers full in one Minute, which is 52 Gallons; and at that Rate, in an Hour's Time, may be flung up 3110 Gallons, which at 60 Gallons to the Hogshead, is 52 Hogsheads: So that were this small Engine to work, it would throw up 1248 Hogsheads (if Mr. Bradley's Calculation is right) in 24 Hours. And if there were two Receivers, which is generally practis'd in Coal Works, the one to suck, while the other discharges it self, then there would be rais'd 6240 Gallons in an Hour, which is 104 Hogsheads, and consequently a Day would produce 2496 Hogsheads.

THE prime Cost of such an Engine is about 50 Pound, as I my self have had it from the ingenious Author's own Mouth, and the Quantity of Coals requir'd to work it, about half a Peck, which need not be renew'd above 6 or 8 Times, were it to be wrought the whole 24 Hours, which supposing to be a Bushel at most, is not above 12 *d.* in *London*, but much cheaper in many other Places; the Expence is not considerable to what Horse Work is, which must be shifted twice or thrice a Day, especially in all Coal and Wood Countries, where Horses are likewise generally let at dearer Rates, than at other Places, on account of that greater Quantity of Carriage there is in those Places, more than is in others.

THE chief Thing that seems to be objected against the Nature of the Engine just mention'd as to the Expence, is the making the Fire in the open Air as it were, and under a Trivet; because the Heat in such a Latitude will evaporate, and not be so strong, as when it is confin'd into a narrow Compass, and consequently there must be a greater Expence and Waste of Wood and Coal, than when it is thus contracted, which makes it, I think, better to have the Fire enclos'd in a Stove or Furnace, than under any open spherical Figure.

PROCEED we now then to the double Receiver, as we have it from the first Thought of our ingenious Inventor, and after that, to the Improvements that have been since made to it.

A Description of the double Fire Engine, and of the Method of working it, Plate 24. Fig. 2 and 3.

THE foregoing Chapter treating of the Method of working the single Fire Engine, which may serve for the Supply of any reasonable small Family, and Gardens thereunto belonging, it is requisite in the next Place, that we consider the double Barrel and double Furnaced one, which is requir'd in all large Buildings and Gardens,
as

as well as Mines, and other deep Places, which is extracted from the Author's own Account of it, in a little Treatise before mentioned, call'd, *The Miner's Friend*, publish'd also in the Transactions of the Royal Society, Numb. 252.

A Description of the Engine, Plate 24. Fig. 1.

- A, The Furnaces.
- B B, The two Fire Places.
- 12
- C, The Funnel or Chimney.
- D, The small Boiler.
- E, The Pipe and Cock of it.
- F, The Screw that covers and confines the Force.
- G, A small Cock to a Pipe going within eight Inches of its Bottom.
- H, A larger Pipe going the same Depth.
- I, A Clack on the Top of the said Pipe.
- K, A Pipe going from the Box of the said Clack or Valve, into the great Boiler, about an Inch into it.
- L, The great Boiler.
- M, The Screw with the Regulator.
- N, A small Cock and Pipe going half Way down the great Boiler.
- O O, Steam Pipes, at one End of each are
- 1.2, Screws to the Regulator, and the other End to the Receivers.
- P P, The Vessels call'd Receivers.
- 1.2, Screws to P P.
- Q. The Screws which bring on the Pipes and Clacks into the Front of the Engine.
- R R R R, Numb. 1. 2. 3. 4. Valves or Clacks of Brass, with Screws to open and come at them upon Occasion,
- S, The Force Pipe.
- T, The sucking Pipe.
- V, A square Frame of Wood, with Holes round its Bottom in the Water.
- X, A Cistern, with a Buoy Cock, coming from the Bottom of the said Cistern.
- Z, The Handle of the Regulator.

THE Manner of working this Engine is, first, there is a good double Furnace, so contriv'd, that the Flame of your Fire may circulate round, and encompass your two Boilers to the best Advantage, as you do Coppers for brewing. Before you make any Fire, unscrew

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G and N, being the two small Gauge Pipes and Cocks belonging to the two Boilers. And at the Holes fill L the great Boiler two thirds full of Water, and D the small Boiler quite full; then screw in the said Pipes again as fast and tight as possible. Then light the Fire at B N^o. 1. When the Water in L Boils, the Handle of the Regulator mark'd Z, must be thrust off from you as far as 'twill go, which makes all the Steam, rising from the Water in L, pass with irresistible Force through O N^o. 1. into P. N^o. 1. making a Noise as it goes; and when all is gone out, the Bottom of the Vessel P, N^o. 1. will be very hot. Then pull the Handle of the Regulator towards you; by which Means you stop O. N^o. 1. and force your Steam through O. N^o. 2. into the P. N^o. 2. until that Vessel has discharg'd its Air through the Clack R. N^o. 2. up the Force Pipe. In the mean Time, by the Steam's condensing in the Vessel P. N^o. 1. a Vacuum or Emptiness is created, so that the Water must and will necessarily rise up through I the sucking Pipe, lifting up the Clack R. N^o. 3. and filling the Vessel P. N^o. 1.

IN the mean Time, the Vessel P. N^o. 2. being emptied of its Air, turn the Handle of the Regulator from you again, and the Force is upon the Surface of the Water in P. N^o. 1. which Surface being only heated by the Steam, it does not condense it, but the Steam gravitates, or presses with an elastick Quality like Air; still increasing its Elasticity or Spring, till it counterpoises, or rather exceeds the Weight of the Water ascending in S the forcing Pipe; out of which the Water in P. N^o. 1. will be immediately discharg'd, when once gotten to the Top; which takes up some Time to recover that Power, which having once got, and being in Work, it is easy for any one that never saw the Engine, after half an Hour's Experience, to keep a constant Stream running out the full Bore of the Pipe S. For on the out-side of the Vessel P. N^o. 1. you may see how the Water goes out, as well as if the Vessel was transparent; for as the Steam continues within the Vessel, so far is the Vessel dry without, and so hot, as one is scarce able to endure the least Touch with one's Hand; but as far as the Water is, the said Vessel will be cold and wet, where any Water has fallen in it; which Cold and Moisture vanishes as fast as the Steam in its Descent takes Place of the Water. But if you force all the Water out, the Steam, or a small Part thereof going through R. N^o. 1. will rattle the Clack so, as to give sufficient notice to pull the Handle of the Regulator to you; which at the same Time begins to force out the Water from P. N^o. 2. without the least Alteration of the Stream; only sometimes the Stream of Water will be somewhat stronger than before,

fore, if you pull the Handle of the Regulator before any considerable Quantity of Steam be gone up the Clack R. N^o. 1. but it is much better to let none of the Steam go off (for that is but losing so much Strength) and is easily prevented, by pulling the Regulator some little Time before the Vessel forcing is quite emptied. This being done, immediately turn the Cock or Pipe of the Cistern X on P. N^o. 1. so that the Water proceeding from X through L Y (which is never open, but when turn'd on P. N^o. 1. or P. N^o. 2. but when between them is tight and stanch) I say, the Water falling on P. N^o. 1. causes by its Coolness the Steam (which had such great Force just before) by its elastick Power, to condense, to become, in the Language of our Author, a Vacuum, or empty Space. So that the Vessel P. N^o. 1. is by the external Pressure of the Atmosphere, or what is vulgarly call'd Suction, immediately refilled, while P. N. 2. is emptying: Which being done, you push the Handle of the Regulator from you, and throw the Force on P. N^o. 2. causing the Steam in that Vessel to condense, so that it fills while the other empties: The Labour of turning these two Parts of that Engine, *viz.* the Regulator and Water-Cock, and tending the Fire, being no more than what a Boy's Strength can perform for a Day together.

THE ingenious Reader will probably here object, that the Steam being the Cause of this Motion and Force, and that Steam is but Water rarified, the Boiler L must in some certain Time be emptied, so as the Work of the Engine must stop to replenish the Boiler, or endanger the burning out, or melting the Bottom of the Boiler.

To answer which, be pleas'd to observe the Use of the small Boiler D. when it is thought fit by the Person tending the Engine, to replenish the great Boiler (which requires an Hour and an Half, or two Hours Time, to the sinking one Foot of Water): Then, I say, by turning the Cock of the small Boiler E, you cut off all Communication between S the great Force Pipe, and D the small Boiler; by which Means D grows immediately hot, by throwing a little Fire into B. N^o. 2. the Water of which boils, and in a very little Time it gains more Strength than the great Boiler; for the Force of the great Boiler being perpetually spending and going out, and the other winding up, or increasing, it is not long before the Force in D exceeds that in L; so that the Water in D being depress'd in D by its own Steam or Vapour, must necessarily rise through the Pipe K into L, running, till the Surface of the Water in D is equal to the Bottom of the Pipe H.

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THEN the Steam and Water going together, will by a Noise in the Clack I give sufficient Assurance, that D has discharg'd and emptied itself into L, to within eight Inches of the Bottom: And in as much as from the Top of D, to the Bottom of its Pipe H, is contain'd about as much Water as will replenish one Foot; so you may be certain, L is replenish'd one Foot of course: Then you open the Cock I, and refill D immediately.

By which you will see, that here is a constant Motion, without Fear or Danger of Disorder or Decay; and if you would at any Time know if the great Boiler L be more than half exhausted, turn the small Cock N, whose Pipe will deliver Water, if the Water be above the Level of its Bottom, which is half Way down the Boiler, if not, it will deliver Steam.

So likewise will G shew you, if you have more or less than eight Inches of Water in D, by which Means nothing but a stupid Neglect, or mischievous Design carried on some Hours, can any Ways hurt the Engine. And if a Master is suspicious of the Design of a Servant to do Mischief, it is easily discovered by those Gauge Pipes: For if he comes when the Engine is at Work, and finds the Surface C of the Water in L, below the Bottom of the Gauge Pipe N, or the Water in D below the Bottom of G. such a Servant deserves Correction; tho' three Hours after that, the working on would not damage or exhaust the Boilers: So that in a Word the Clacks being in all Water-Works always found the better the longer they are us'd; so here the same Effect is found, and all the moving Parts of the Engine being of like Nature, the Furnace being made of *Sturbridge* or *Windsor* Brick, or Fire Stone, I don't see it possible for the Engine to decay in many Years.

FOR besides all the Clacks, Boxes, and Water-Pipe, Regulator, and Cocks are all of Brass; and the Vessels are made of the best hammer'd Copper, of sufficient Thickness to sustain the Force of the Working-Engine: In short, the Engine is so naturally adapted to perform what is requir'd, that even those of the most ordinary and meanest Capacity may work it for some Years without Injury, if not hired or employ'd by some base Person on Purpose to destroy it: For after the Engine is once fix'd, and at work, I may modestly affirm, that the Adventurer or Supervisor of the work will be freed from that perpetual Charge, Expence and Trouble of Repairs, which many Engines are generally liable to.

THUS far the Ingenious Captain *Savery* as to the Working of his Engine; many other Instructions has he likewise left us to the fixing

fixing his Engine, for the Service of Gentlemens Houses, Coal-Works, &c.

ALL which, with other Necessaries, may I think be summ'd up in these few Lines, that the Engine be fix'd on the highest Ground, or as near as possible the Reservoir that is to supply the House and Gardens, if in the open Air; for the Advantage of this as well as the Chain-Pump, is that you may use them on the highest Hill, and they certainly save that Expence of Pipe which is unavoidable where-ever you force up your Water by Crank-Work, not but they are useful where Cranks are too. But if you are to force up your Water to the Top of a high Tower, then of course you must place your Engine therein, and one and the same Building will serve.

It is observable, that all those Engines that are plac'd so as to raise Water to a considerable Height, that the Furnaces are plac'd about 21, 22 or 23 Feet, and sometimes more, above the Surface of Water in the Well or Pond, out of which you are to draw the Water; because the external Pressure of the Air, or in other Words the Atmosphere forces the Water by Nature up to that Height where this Engine takes it, as it does in all other Pumps and Engines.

To follow our Author for Palaces, or the Nobility's, or Gentlemens Houses, you may fix the Engine in any remote or out-Room, whose Floor as before is not above 20 or 25 Foot from the Level of your Water; but in Case the Surface of the Water is apt to rise and sink, as many Springs are apt to do, there you must take the lowest: But you may continue your force Pipe up to the Top of your Houses, be it 70, 80 or 100 Feet, making your Furnaces either larger or smaller, according to the different Heights you are to throw your Water; at the top of which House you are to fix your Cistern, into which the Pipes also must be laid that are to convey the Water to its several Uses.

THIS way of Cisterns on the Tops of Houses or Palaces would be of singular Use in case of Fire, as is said before; for in every Stair-Case a Pipe may go down the Corner, or behind the Wainscot, so as to be no Blemish even to the finest Stair-Case.

At every Floor there may be a Turn-Cock with a Screw; at the utmost End you may likewise have a small Leather Pipe kept well oil'd in a Cupboard or Cavity in your Wall, which may not be seen but on the opening some Part of the Wainscot; or such other Contrivance as the Ingenious Builder shall think fit to make use of. This Pipe of Leather must be long enough to reach from the Landing Place or Stair-head into all the Rooms adjoining to it.

ONE End of this Pipe may have a Screw to fit the Cock in the other Pipe ; and at the other End a Pipe like the Nose of a Pair of Bellows ; so that wherever, though under a Bed, or the remotest part of any Room in the House, the Fire breaks out or is discover'd ; any Servant having screw'd the Pipe to the Cock, stops the Nose with his Thumb till he comes to the Place where the Fire is, when taking away his Thumb, he by directing the Nose to the Fire, immediately extinguishes it ; which being liable to be instantly used, I think a House, Palace, &c. that has this Invention, may be said to be morally out of Danger of being destroy'd or so far injur'd, as *Whitehall* and *Kensington* have within these few Years been.

THIS Command of Water must be allow'd to be a vast Advantage to any House whatsoever, where Brewing, Washing, &c. is used ; the Copper standing high, may be fill'd as easy as if it stood low, by which means the hot Liquor may be contriv'd to go to all your Coolers and other Vessels, either by a Siphon, Stop-Cock and the like, without the Labour of Pumping or Boiling with Buckets.

How useful it is in Gardens and Fountain-Works may or might have been seen in the Garden of that Right Noble Peer the present Duke of *Chandois*, at his late House at *Sion-Hill* ; where the Engine was plac'd under a delightful Banquetting-House, and the Water being forc'd up into a Cistern on the top thereof, us'd to play a Fountain contiguous thereto in a very delightful Manner.

FOR the Draining of Fens and the like, this Engine is no less useful, but must be made very large in the Bore of the evacuating Pipe ; for at all small Heights a small Quantity of Fire will deliver a prodigious Quantity of Water. For suppose we suck twenty Foot, if the Boiler does but fill the Vessels called Reservers, with Steam strong enough to counterpoise or exceed the Force of the Atmosphere, or Spring of the common Air, it will discharge them at so small a Height as 30 Foot Force in a very little Time : And the Steam having very little Force is immediately condensed, so that it will presently suck full, in one of the Vessels, while the other is discharg'd.

NOW in as much as the Fire being more or less, adds nothing to the Suction ; I think such Lifts being seldom above 36 or under 6 Foot, all the Directions farther needful for the fixing the Engine for this Use, is in all Lifts under 20 Foot ; to place your Engine so as a little above your Force-Clacks, may be the Place of the Delivery of your Water into a convenient Reservoir or Trough, to be carried off at the most proper Place for its Discharge.

IF it be any Height above 24 Foot or thereabouts, you have nothing to do but to continue the Length of your force Pipe to the
Height

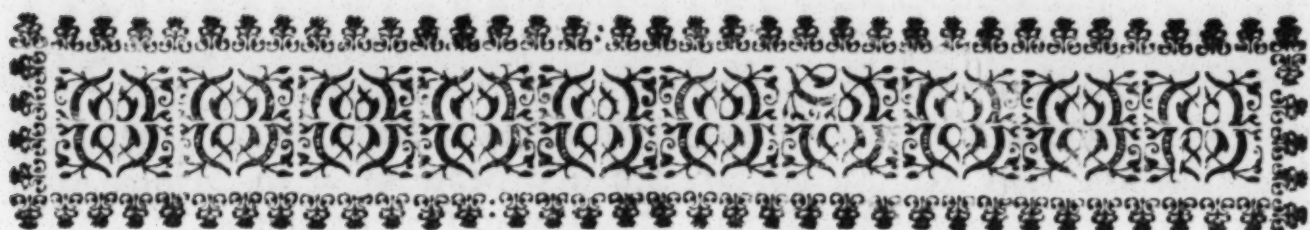
Height requir'd ; it ought to have a Shed or Covering, not only in this (but in all other Places) and to be plac'd at the lowest Place of your Fen or Bog, as other Engines design'd for that Purpose generally are : And thus much of the Uses and Manner of fixing it, as I have it from the Author, or from what has occur'd to my own Observation on this Head ; as for the Working of it in Mines and Coal-Pits, I refer the Reader to the Author's Treatise it self, as it is Printed for *S. Crouch* at the Corner of *Pope's-Head-Alley* in *Cornhill*, Anno 1702.

PROCEED we now, according to Promise, to a Capitulation of the Improvements that have been made to this useful Engine, which will be in a great Measure summ'd up in that Noble Engine erected for the Use of the *York-Buildings*.

To finish this long Account of the surprising Engine for the raising of Water by Fire : I produce this last Improvement of it by Mr. *Thomas Newcomen*, which makes it undoubtedly the beautifullest and most useful Engine that any Age or Country ever yet produc'd.

THE following, *vid.* Machine, *Plate 25.* differs in no essential Part from that set up at the *York-Buildings*, only the Pump-Work is double : And all Engines that are in Mines have their Pumps under Ground, fix'd in the Pit : The Pumps being either sucking, lifting, or forcing Pumps, according to the Conveniency or Circumstances of the Place.





C H A P. XXIX.

A Description of the Engine to raise Water by Fire, fix'd in a Frame of Timber instead of the usual Engine-House, as Improv'd by Mr. NEWCOMEN.

A 1, A 2,



H E Leaver, or great Beam of the Engine, moving upon its Centre at C, whose Ends are alternately pull'd down by the Piston in the Cylinder, and by the Plug or Forcer of the Pump.

a 1, a 4, a 2, a 3, The Arches fix'd to the Ends of the Beam, to carry the Chains that sustain the Piston and the Plug; in order to have the Strokes perpendicular in the Cylinder, and the Forcing-barrel or Working-piece, in the Lines a 4 and a 6.

C c 1, C c 2. Two strong wooden Springs, to weaken the Blow given by the Bars at the Ends of the Leaver when the Stroke is too long, that the Machine may not receive too great a shock.

a 1, a 2. Two strong Iron Bars crossing the two extreme Arches of the Leaver, to prevent the Ends from coming down too low in case the Chain at either end should break.

D. Another little Arch upon the Beam, to carry a Chain that draws up and lets down the working-Timber p p 1, p p 2, (by the Engineers belonging to the Mines call'd *the Plug-Frame*) which, in rising and sinking perpendicularly, does, by its several Pins, alternately open and shut the Regulator T, and the Injection-Cock m.

E. The Rod which, hanging at the Chain of the Arch a 2, a 3, draws up and lets down the loaded Forcer or Plug; which Forcer, by its motion in the Working-piece, or Forcing-barrel F, brings up, out of the Well under it, and forces up thro' the Pipes, into the Reservoir, a Column of Water almost as heavy as the said Forcer; which

which is only loaded with so much more weight as to give the Water a sufficient Velocity, that the Quantity requir'd may be rais'd and deliver'd into the Reservoir in a given time: And, that neither Air nor Water may pass between the said Forcer and Barrel, it goes thro' two Collars of Leather, which are screw'd between three Rings of Metal fix'd on the upper Flanch of the said Forcing-barrel. The middle Ring is of Brass, and serves for a Guide to the Forcer, being of a lesser bore than the other two, which are of Iron, that neither the upper Leather nor the lower Leather (one whereof is turn'd upwards, and the other downwards) may slip between the Forcer and the middle brass Ring; as may be seen in Fig. 3, which represents a Geometrical Section of the Pump-work, seen in front, with the Forcer, Rod, Screws, and Weights; the two sucking and forcing Valves; part of the sucking Pipe, and part of the forcing or ascending Pipe; the small Pipe, which discharges the Air, with its Cock and Valve; the leaden Cup with Water (to the height of the pointed Line) to moisten the Leathers which are represented by strong black Lines.

F 8, 10, 9, 7, H 6, G 1. (*Vid. Fig. 3. Plate 25*) is The Pump-work, consisting of the following Pieces, *viz.* F 7, 8, the Forcing-barrel, which is bigger in its Bore at 7, 8 than in any other part, to allow sufficient Water-way, when the sucking Valve fix'd at the level of 9, 10 rises up as the Forcer is rais'd. This Barrel has a curve Elbow H coming out of it just above the sucking Valve, and the Elbow has a Flanch under 6, to carry the forcing Valve which plays in the swell 6 of the Piece 6, G 1. The sucking Pipe which goes down into the Well has only its Flanch 9, 10, and a small part below it (mark'd 11) seen here: And it is upon this Flanch 9, 10 (the Flanch of the forcing Barrel) that the sucking Valve is fix'd, which rises when the Forcer is lifted up, and allows the Water to rise which the Atmosphere presses up from the Well, to fill the space left empty by the Forcer; the forcing Valve under 6 being shut all this while: Then, as the Forcer comes down again, it presses a quantity of Water equal to its bulk thro' the forcing Valve under 6 into the Piece G 1, the sucking Valve being shut at that time; and so on, till the Water is driven up thro' the Pipes G 1, G, G, G, into the Trough I, I, which carries it into the Reservoir K, K, K, K, K, K, K. NB. *The Forcer is a hollow brass Cylinder fill'd with Lead, turn'd true and smooth on the outside.*

L, The Injection Cistern, for the Uses of the Engine, to be mention'd hereafter.

M, M, M, M, The two strong Timbers which support the Leaver by its Centre or Axis, and between which the Leaver plays.

X x

N, The

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N, The Chain that supports the Piston, which always hangs perpendicular, because its upper part always applies it self to the Arch at the end of the Leaver, whilst the free part is a Tangent to the said Arch.

O, O 1, O 2, The Injecting Pipe, which coming from the Injecting Cistern L at O 2, gives out a little Pipe at O 1, to let Water run upon the Piston, to keep it tight, by moistening and cooling its Leather, and at last goes into the Cylinder at O thro' a Flanch, in such manner, that an Adjutage or spouting Pipe is screw'd on the upper part of the end of it which is in the Cylinder. The Use of this Pipe is, to spout cold Water into the Cylinder, in order to condense the Steam, and make a *Vacuum* under the Piston, when it has been rais'd up to the top of the Cylinder, that the Atmosphere may press it down again with force and swiftnes.

P 1, P 2, The Cylinder, made of Brass, hollow within, and bor'd very smooth, that the Piston P 1, mark'd in pointed Lines, may move up and down in it from P 1 to P 2, without letting either Steam or Water pass by. This Cylinder has a leaden Cup solder'd to the top of it under N, so wide, that the Water that lies at the top of the Piston to cool its Leather may not flash over the top of the Cylinder in the sudden rising of the Piston.

Q, The Steam-pipe, thro' which the Steam passes from the Boyler into the Cylinder.

R, R 1, R, R, R 2, The Boyler, made hemispherical at top, and then diminishing at right Angles, or with a Flanch, at R 1, R 2, and so continuing almost in a Cylindrick form to the bottom; which is rising in the middle, as appears by the pointed Lines.

S, A brass Plate screw'd to the Boyler with four or more Screws, which, when taken off, opens a way into the Boyler in order to cleanse it, &c. On this Plate is fasten'd a short Pipe and Valve, S 1, with a Stillyard and Weight supported by a perpendicular Piece, S 2, in order to know the strength of the Steam in the Boyler, and to prevent its burning, if neglected. In this Plate are fix'd two Gage-Cocks, z 1, z 2, whose Pipes are of different Lengths, in order to know how high the surface of the Water is in the Boyler; for if both Cocks, being open'd, give Steam, the Water is too low; and if both give Water, or give no Steam, then the Water is too high; but if z 1 gives Steam, and z 2 does not, then the surface of the Water is at a due height, viz. above z 3, the bottom of the longest Gage-pipe.

T, The Steam-Cock or Regulator, consisting of a large brass Plate and a Pipe reaching up to Q, which makes half of the Steam-pipe, and is there solder'd to the other half that comes down from the

the bottom of the Cylinder. By means of the Handle *b b*, a little smooth Plate, mark'd 16 (Fig. 2.) under the Regulator Plate, is mov'd in such manner, as alternately to shut and leave open the hole of the Steam-pipe, so as to perform the Office of a Cock, but with a great deal less Friction.

V, A Cock to let Water out of the Boyler upon occasion.

W, A Pipe to feed the Boyler with lukewarm Water from the Cup at the top of the Piston, thro' the Feeding-pipe *n n*, which goes down into the Boyler within a few Inches of its bottom, that there may always be a due Quantity of Water in the said Boyler.

XX, A waste Pipe to carry off the superfluous Water from the Cup at the top of the Piston.

Y Y Z, The Sinking-pipe to carry off the Water which is injected into the Cylinder at every stroke, whose end Z (mark'd in pointed Lines) is turn'd upwards with a Valve upon it, kept tight (when shut) by a little Water in the hot Well Z: But every time the Steam is let into the Cylinder, it opens the Valve at Z, and discharges the Water, as long as the said Pipe Y Y continues full, or nearly full, to help the Steam by the pressure of its Water, which is always proportionable to its height in the said Sinking-pipe.

a, a, a, a, a, a, The Chimney and Brickwork about the Boyler, being here seen only on the back-side; the Fire-place, represented by the pointed Lines at G, being on the other side, and the Flue carried round the Boyler, under its Flanch.

b b, The Handle of the Regulator, mov'd backward and forward by the Motion of the Slider b c.

d, d 1, The Tumbling-piece, commonly call'd the [Y] from its Figure, moveable upon an Axis *e e* by means of the Shanks *g b* and *g g*, which are thrown backwards and forwards, by the Pins in the Working-timber, or Plug-frame, one Pin *a* (on its outside) depressing *g g* in the descent of the Working-timber, so as to throw the Head of the [Y] loaded with Lead to *d 1* (as here in Fig. 1. and Fig. 2) whilst one of its Toes, at the other end, striking the Pin *c d*, shoots forward the Slider, and opens the Regulator: Then a Pin or Roller upon a Pin *b b*, in a Slit made thro' the middle of the Working-timber, in the rising of the said Timber, lifts up the Shank *g b*, and throwing the Weight *d 1* towards the Cylinder, causes the other Toe at the contrary end of the [Y] to strike the Pin *c d* on the inside, and thereby pulls back the Slider to shut the Regulator.

f 1, f 2, A small Iron Leaver, commonly call'd the [F], moveable upon its Axis *r*, which is fix'd in the piece *i*; whose Office is to open and shut the Injection-Cock *m*, by means of two Toes *n, o*, which

take between them the Handle of the said Cock *m*. The Centre of this Leaver is above its Toes, between *f* 1, *f* 2; and one of its ends *f* 2 lodges it self in the Notch of the Catch *r* 1, whose Foot is fix'd upon the Axis *r* of the said Leaver. When the Working-timber ascends, a Tooth, which is fix'd on the side of it that looks towards the Cylinder, express'd here in pointed Lines, raises up the outmost end of another Catch mark'd *q*, (one part of which is hid by the Working-timber *p p*) and consequently draws down the farther end, which takes along with it the nearest end of the Catch *r* 1, which is upon the same Line, and close to the other, whilst the end *p* of the said Catch *r* 1 rises towards *s*, and thereby lets fall out of the Notch the end *f* 2 of the Leaver, which, being pull'd down by the Weight *f* 3 fix'd to it, causes one of the Toes, mark'd *n*, to push towards the Working-timber the Handle of the Cock *m*, which thereby gives the Injection: Then, as the Working-timber descends, by a Pin on its further side it pushes down the Curve-end or longest Shank of the [F] viz. *f* 1; and raises up the other end of it, so as to lodge it in the Notch of the Catch *r* 1; the other Toe, mark'd *o*, pushing the Handle forward at the same time, and thereby shutting the Injection immediately before the opening of the Regulator: as the Injection afterwards must be open'd just after the shutting of the said Regulator. From the Beams which support the Cylinder there come generally two descending Pieces, to carry the Machinery that turns the Regulator and Injection-Cock, commonly call'd the [F] and [Y], at a due distance from the Working-timber; but here, for want of room, two Iron Bars are us'd, one of which is mark'd *i* 3, *i* 4, join'd at bottom by a cross Bar, and with Side-pieces *i*, *i* 1, *i* 2, to carry the Axes of the [F] and [Y]: The other descending Iron Bar can't be seen in this Draught, as being hid by the Working-timber. NB. *For the better understanding of the Motion of the Machine, the Regulator and Injection-Cock, with the other Parts belonging to them, are drawn in large in the same point of Sight, and are mark'd with the same Letters in Fig. 2.*

k k, The two ends of a Strap of Leather fasten'd to the top of the [Y] at *d* 1, to keep it from falling too far either way.

l, The *snifting* Valve, to let out the Air that extricates it self from the injected Water at every stroke, and which would hinder the due Operation of the Engine, if it was not driven out at this Valve.

o, A Cup and Valve to receive some of the injected Water, which is much hotter than the Water above the Piston: From this Cup hot Water is convey'd into the Feeding-pipe *n n*, by the Cock *o* 1.

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p, p 1, p, p 2, The Working-timber, hanging by a Chain which applies it self to the Arch D, and moving up and down perpendicularly thro' the holes *p 1, p 2*, made to keep it steddy in its motion. This Timber has a Slit in the middle from *p 1* down below *p*, in order to receive the Shank *g b*, and to throw it back again by a Pin *b b*, or Roller on the Pin, in the said Slit. There are also Holes on the right and left side of this Timber to put in Pins, as *a*, and *d*, alternately to depress the Handle *g g* on the one side, and the long Shank of the [F] on the other side, according as the motion of the Engine requires.

q, q, q, q, Two strong horizontal Timbers that support the Cylinder by means of a Flanch on the middle of the Cylinder, and Bolts and Screws thro' the said Beams.

r 1, r 2, A cross horizontal Timber, broken off in the Figure, to shew the Cylinder and Pipes, &c.

s, s, s, s, Braces also broken off.

t, t, A Seat and Platform to go from the Working-piece to the Pump.

u, u, One of the upright Timbers that support the Spring-frame and Pipes join'd to the horizontal Piece at M, the other Timber being behind.

u 1, The brass Guide for the Rod of the Forcer, which is here almost hid by the ascending Pipes.

w, w, w, w, w, The Joys of the Floor, which is even with the middle of the Cylinder.

x, x 1, A Cup of Lead, which keeps moist the *Jack-head* or Collar of Leathers. NB. *At first working, the Air is let out of the Jack-head by loosening some of its Screws, or by a little Cock and Valve at x 1.*

y, A cross Piece, which holds the Brass Guide above-mention'd at *u 1*.

æ, A Pipe to supply the Injection-Cistern L with Water from the Reservoir K.

Thus far of the Description of the Engine to raise Water by Fire, as improv'd by Mr. *Newcomen*.

What I have to add in this Place is, that as the best and most useful Inventions and Improvements which have been discover'd either in Art or Nature, have in Process of Time been liable to Improvement; so this of the Fire-Engine has been subject to the same: For this ingenious Gentleman, to whom we owe this late Invention, has with a great deal of Modesty, but as much Judgment,

ment, given the finishing Stroke to it. It is indeed generally said to be an Improvement to Mr. *Savery's* Engine; but I am well inform'd, that Mr. *Newcomen* was as early in his Invention, as Mr. *Savery* was in his, only the latter being nearer the Court, had obtain'd his Patent before the other knew it; on which Account Mr. *Newcomen* was glad to come in as a Partner to it. To which I shall add, that the Gravity of the Atmosphere on the Cylinder, mark'd P 1. P 2. is computed to be equal to 1400 Weight, which nevertheless will not stop the working of the Engine, if the Stoker takes Care to keep his Fire in, and that this Engine is by no Means in so much Danger of being blown up, or broke to Pieces, as Mr. *Savery's* is, by reason of the great Regulator, mark'd A 1. A 2. and of the other, Work at f 1. f 2. &c. which bridle the whole Motion of the Engine. And the utmost Damage that can come to it, is its standing still for want of Fire. What is very remarkable (besides other Things which might be mention'd) is the wonderful Effects there is between the two opposite Principles of Expansion and Condensation, and how fully the Atmosphere performs its Office on this Occasion.

THE Fall of the two Pistons, or Brass Barrels, which are joyn'd to the other End of the Leaver, mark'd a 3. a 4. is also very curious; because that by Means of the Chain fix'd at the End going down to N the Force is exactly perpendicular, and the whole not liable to that Friction, which is almost unavoidable in all other Leaver Work.

THE two Mains which lead from the 2 Barrels, or forcers from the Bottom to the Top of the wooden Turret, are each of them about 12 or 14 Inches Diameter, and deliver about 150 Tuns in an Hour, which is 3600 Tuns, or 14400 Hogsheads in a Day.

To conclude this Account of Engines, I observe, that there are 5 of those Machines of *London Bridge*, one whereof is describ'd *Plate 21. Page 320.* to every one of which is fix'd 4 main Pipes, two at one End, and two at another, in all 20, of 7 Inches Bore each; the Workmen there have not, as I can find as yet, calculated, (at least it is out of Mind) what Quantity of Water, all those Machines will throw up in an Hour, tho' if the Pipes are kept perpetually full, as an Engine with 4 Cranks certainly will, according to *Marriotte*, in 20 Mains, of 49 circular Inches each, making in all 980 circular Inches; those Machines can't give less than 1715 Hogsheads in an Hour, and consequently 45160 Hogsheads in a Day, equal, if not exceeding what the so much fam'd one of *Marli* does, and that without any great need of Repairs.

ONE Thing observable in the Wheels of those Machines is, that they turn as the Tide does; those which are plac'd near the Middle, are either elevated or depress'd by a little Wheel on the Back Part of the Work, called a lifting Wheel, as the Tide either rises or falls, whilst those which are plac'd near the outside, are kept to a constant Gauge, which is all I shall add in this Place as to these Machines.



CHAP XXX.

Of several Machines for the playing of Musick.



Have already, in my Introduction to this Book of Hydraulicks, noted, that it has had its real Denomination (though now it is generally applied to all Water Engines) from ὕδωρ *Aqua* Water, and αὐλός *Tibia vel Tibicen* a Pipe, from the Uses which the Ancients put the Antlia or Pump to in blowing their Organs; and of this Kind there are Inventions of a late Date (as whoever reads *de Caus*, and other Authors, will find) by which Organs, and other Instruments of Musick are play'd: And tho' this Chapter may not be of the greatest Use, yet there is a Diversion in it, that may not be unacceptable to the curious Reader.

To begin then with the learned *Gravesande*, the undulatory Motion in the Air produces Sound: For (speaking of Sensation) so strict is the Union of the Body and the Mind, (says he) that some Motions in the Body do as it were cohere with certain Ideas in the Mind, and they can't be separated from each other. From the Motion of the Body are new Ideas every Moment excited in the Mind; and such are the Ideas of all sensible Objects; yet we can find nothing common between the Motion in the Body, and the Idea in the Mind. We cannot perceive what Connection is here, nor that any Connection is possible: There are (according to the great Sir *Isaac Newton*, whose Footsteps this learned Author follows) an infinite Number of Things hidden from us, of which we have not so much as an Idea.

THE undulatory Motion of the Air agitates the Tympanum or Drum of the Ear, by which Means a Motion is communicated to the Air contain'd in that Organ, which being conveyed to the auditory Nerve, excites in the Mind the Idea of Sound.

NOW, to explain a little those Laws of Motion, that produce Sound, let Particles of Air be supposed to be plac'd at equal Distances, and to be in a right Line, *a, a, b, c, d, &c. and f*, Fig. 1. Plate 26. Page 352; let the Wave be suppos'd to move along that Line, as far as between *b* and *p*, as it is represented in Line 1.

THE greatest Density is at *m*, which is the Middle between *b* and *p*, and the greatest Dilatation between (*b* and *b*) is in the Middle (*e*). Wherever the neighbouring Particles are not equally distant, the Motion arising from Elasticity causes the less distant Particles to move towards those that are most distant, between (*b*) and (*e*); there is a Motion from (*b*) towards *e* that is conspiring with the Motion of the Waves; there is also such a Motion between *n* and *p*; but there is a contrary Motion between *e* and *m*, and it is directed from *m* towards *e*. At *m* and *e*, where the Directions of Motions are chang'd, no Action arises from the Elasticity, because the neighbouring Parts are plac'd at equal Distances amongst themselves. In the Places *b, l* and *p*, the Difference of the Neighbouring Parts is the greatest of all; and therefore there is the greatest Action of the Elasticity.

BUT for this Motion or Progression of Sound, I refer my Reader to Book the 2d, Chap. 17. of *Gravesande's Mathematical Elements of Natural Philosophy*, where it is treated of in a very exact Manner, having made use of the Figures in that Treatise set down, for the Embellishment of this Work.

AND to proceed, the Structure of the Ear, both internal and external, is wonderful, but that the Air is the Vehicle of Sound, is proved by the following Experiment.

TAKE the leaden Plate O, *Vid. Fig 2. Plate 26. Page 352*, which has two Cylindrical Pillars of the same Metal C C fix'd to it; joyn a little Bell A to the Brass Wire B D, and let it be tied with Strings to the Pillars C C; lay the Plate O upon the Brass Plate of the Air-Pump, putting between a little Cushion of Cotton, or raw Silk, set a Receiver on over all this *Apparatus*. Cover the Receiver with a Plate that has a Collar of Leathers screw'd to it, thro' which the Brass Wire D E can slip up and down; to the Brass Wire you must fasten the Plate *e f*; so that by twining of the Wire round, the Bell A may be agitated. Pump out the Air from the Receiver, and shaking the Bell in the Manner before described, you

will not hear the Sound. By turning the Wire D E, the Bell will move forwards and backwards several Times; but we are only to observe that Motion in which the Plate *e f* doth not touch the Wire *b d*. Letting in the Air, the Sound will be heard as before.

AND from this it is deducible, that Air is the Vehicle of Sound, and that in Sound there is an undulatory Motion of the Air, and that it arises from the tremulous Motion of Bodies. That this obtains in Cords or Strings of musical Instruments, no body doubts, since by giving them a tremulous Agitation they produce a Sound; in great Bells, and other Bodies this tremulous Motion is very sensible, and in all other Bodies according to their Proportion.

IT appears also, that the Intensity of Sound is as the Weight by which the Air is compress'd; that is, this Intensity increases and decreases as the Pillar of Mercury, which is *in Equilibrio* with the Weight of the Atmosphere, for which see *Fig. 3. Plate 26. Page 350.* where if you shake the Bell A in compress'd Air exactly in the Manner as it was shak'd *in vacuo*, the Sound will be encreas'd; which will again be diminish'd, if opening the Bell, you let the Air return to its first State. For a further Demonstration of what we are upon; and that Air is the certain Vehicle of Sound, which is less or more Intense according to the Warmth or Coldness of the Weather, *i. e.* less in Winter than in Summer; let *Fig. 5. Plate the 26th. prædict.* be a Glass wherein a Bell is hung as A, and opening the Cock that the Air in the Glass may have Communication with the external Air, let the Glass be shaken, and the Distance be determin'd when the Sound can be heard; warm the Glass and repeat the Experiment, and the Sound will be heard at a greater Distance.

IF was agreeable to this, that the Ancients had several Instruments of Musick which sounded when the Sun shined upon them; and *Cornelius Tacitus* in his History maketh mention of such a one in *Egypt*, and *Pausanius* is said to have seen the Figure. The Sound whereof was like the Strings of a Harp when they break.

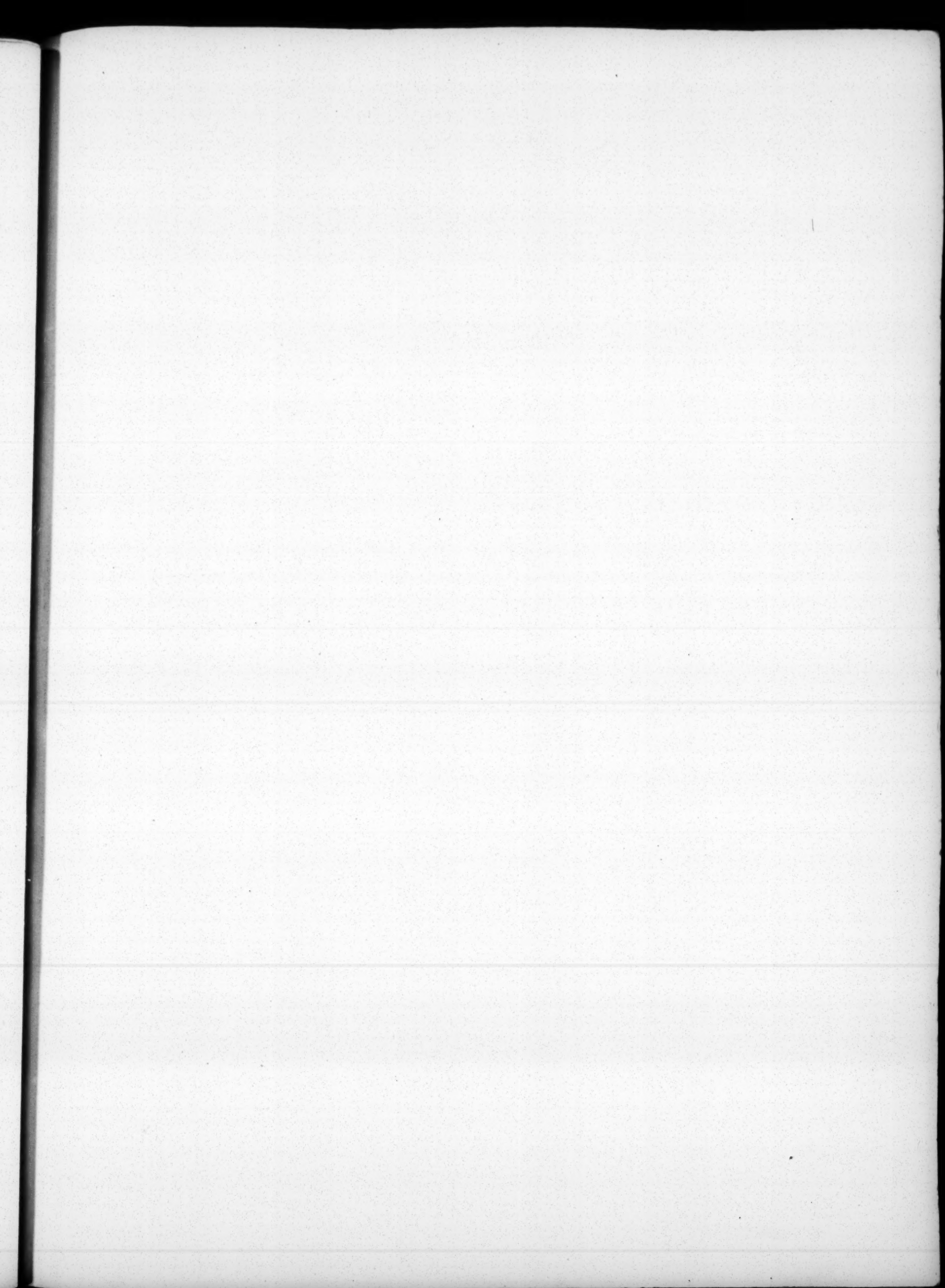
De Caus, from whom this Invention is taken in *Plate 9th* and *10th* of his forcible Movements by Water, &c. teaches the raising of Water in a Vessel of Copper or Lead (by the Heat of the Sun) by means of the Valve at A. *vid. Plate 27. P. 350.* Now when the Water shall be in F, it shall be transported into C by the Siphon B, which casting its Water into C, shall make the Air breathe forth of it, and animate the two Organ-Pipes, which with the Engine may be put into the Figure or Pedestal; or otherwise, if the Engine be put at a Distance, you must use Conveyances for the Wind, and so

the Pipes only may be in the Figure, which being of Brass, and hollow, shall have no Air but by the Mouth; by which the Sound of the Organ Pipes shall come forth.

NOW it is plain, that the Rarefaction of the Air, by the heating the Organ-Pipes by the Sun, as was before-mention'd; and the Methods by which this is effected will more plainly appear by *Fig. 2. Plate 27th, prædict.* of which take the following Account.

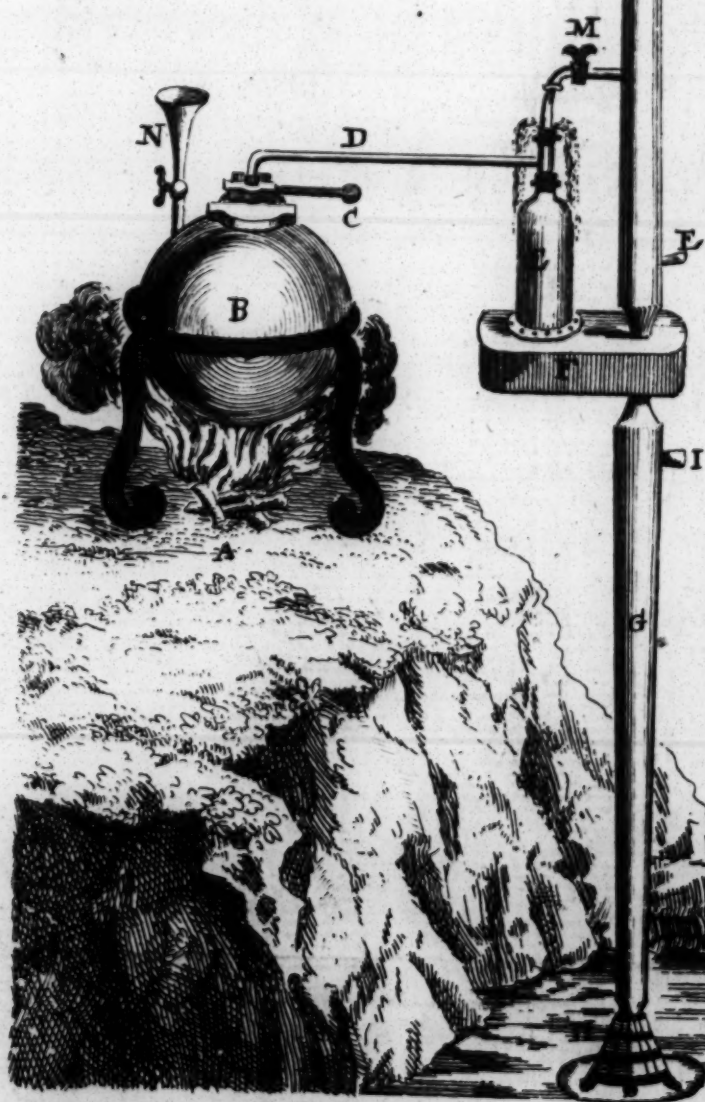
YOU must have four Vessels of Copper well soldered round about; each of which shall be about a Foot square and 8 or 9 Inches high, the Vessels are mark'd with A B C and D, and there must be also a Pipe mark'd with E put upon the said Vessels, to which Pipe there shall be soldered four Branches, each Branch being mark'd with the Letter F, the said Branches shall be soldered to the Top of the Vessels, passing almost to the Bottom of each: Then there must be soldered a Sucker mark'd with G to the middle of the Pipe, made and plac'd so, that when the Water springs out of the Vessel, it may open, and being gone forth, it may shut again.

THERE must be also another Pipe at the Bottom of the said Vessels mark'd with P, to which there is also four Branches, the which must be soldered against the Bottoms of the said Vessels, and also a Sucker mark'd H, to the end of which there is a Pipe which descends to the Bottom of the Water, the which shall be in a Cistern or Vessel mark'd with I: There shall be also to one of the Vessels a Hole or Vent mark'd within; so placing the Engine in a Place where the Sun may shine upon it, pour the Water into the Vessels by the Hole or Vent M, which Water shall be communicated to all the Vessels, by the means of the Pipe P: And the said Vessels must have about a third Part of their Content in Water; and the Air which was in the Place of the said Vessels shall pass out by the Passages 3, 4, 5, 6; afterwards you must stop those Passages very close, so as the Air may not come out of the said Vessels; and then the Sun shining upon the said Engine shall make an Expression, because the Heat which causeth the Water to rise from all the Vessels to the Pipe E, and pass forth by the Sucker G, and the Pipe N, and then fall into the Basin O, and from thence into the Cistern I; and when there shall be a great quantity of Water run forth by the Violence of the Heat of the Sun, then the Sucker G shall return; and after the Heat of the Day is pass'd, and the Night shall come, the Vessels shall draw the Water of the Cistern by the Pipe and Sucker H P, and shall fill the Vessels as before; so as the Motion shall continue so long as there is Water in the Cistern, and that the Sun shines upon the Vessels: And you must observe, that the two Suckers G and H must be made very light; and

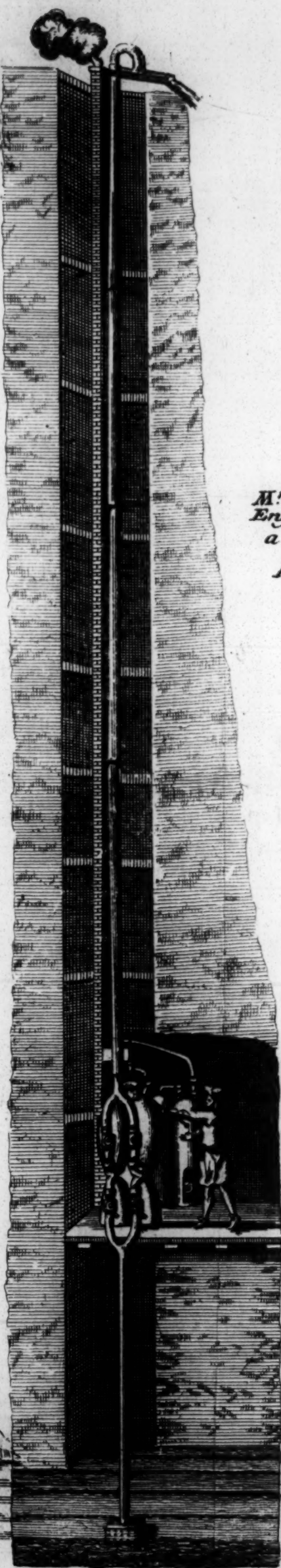


*The Fire Engine at
Holland House as Improv'd
by M^r. Bradley*

Fig 1



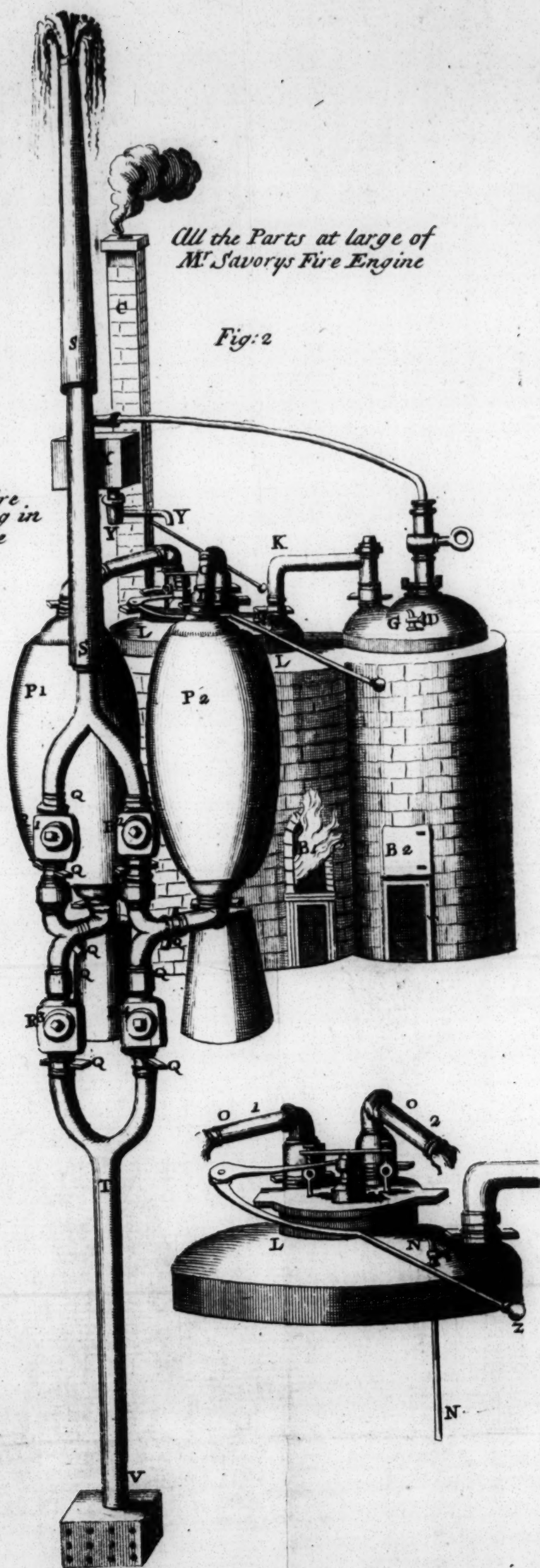
*M^r. Savorys Fire
Engine working
a Deep Mine*
Fig. 3



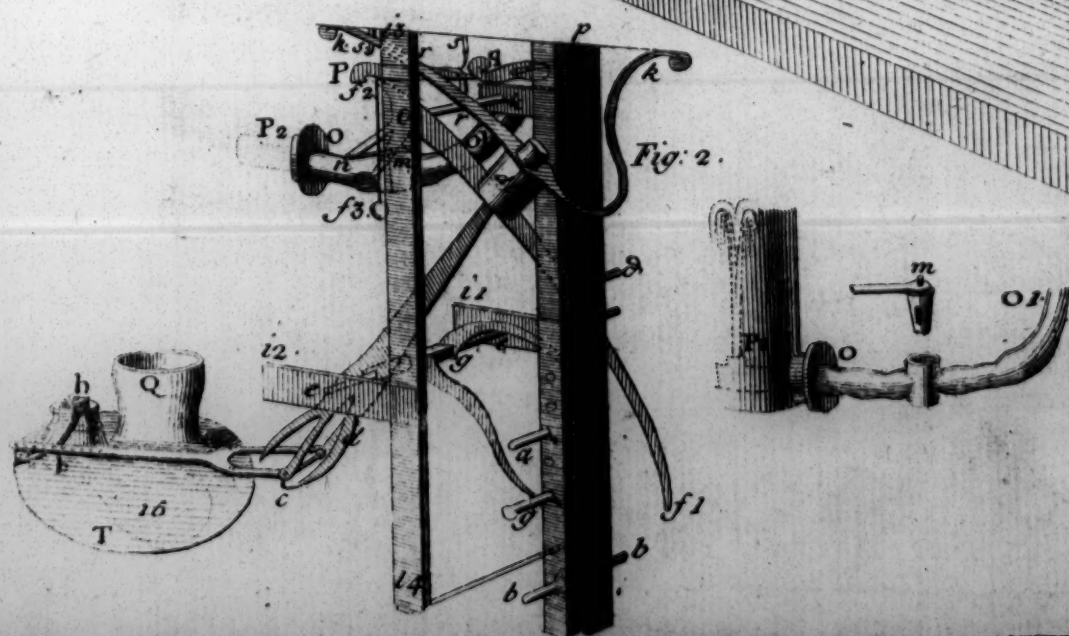
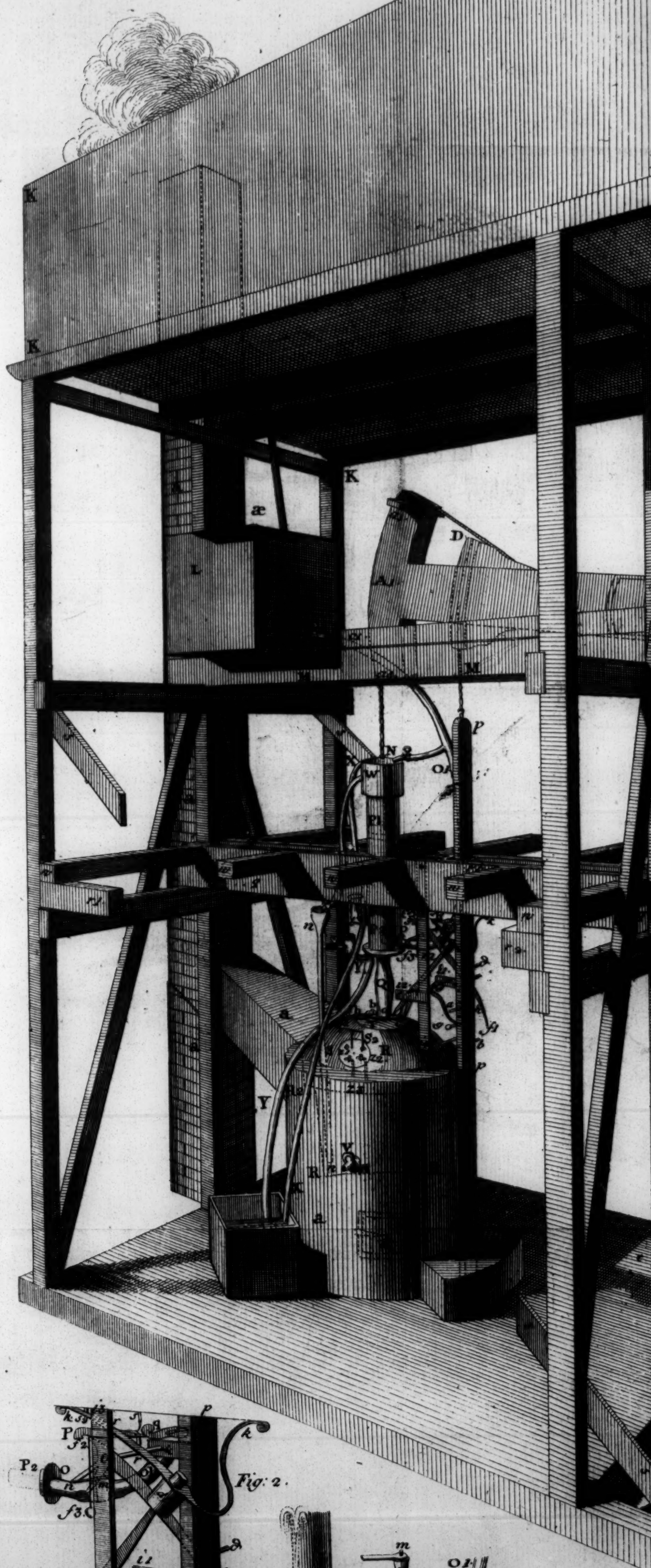
All the Parts at large of
Mr Savorys Fire Engine

Fig: 2

rys Fire.
working in
Mine



A DRAUGHT in PERSPECTIVE of an ENGINE for RAISEING WATER by FIRE.



E for

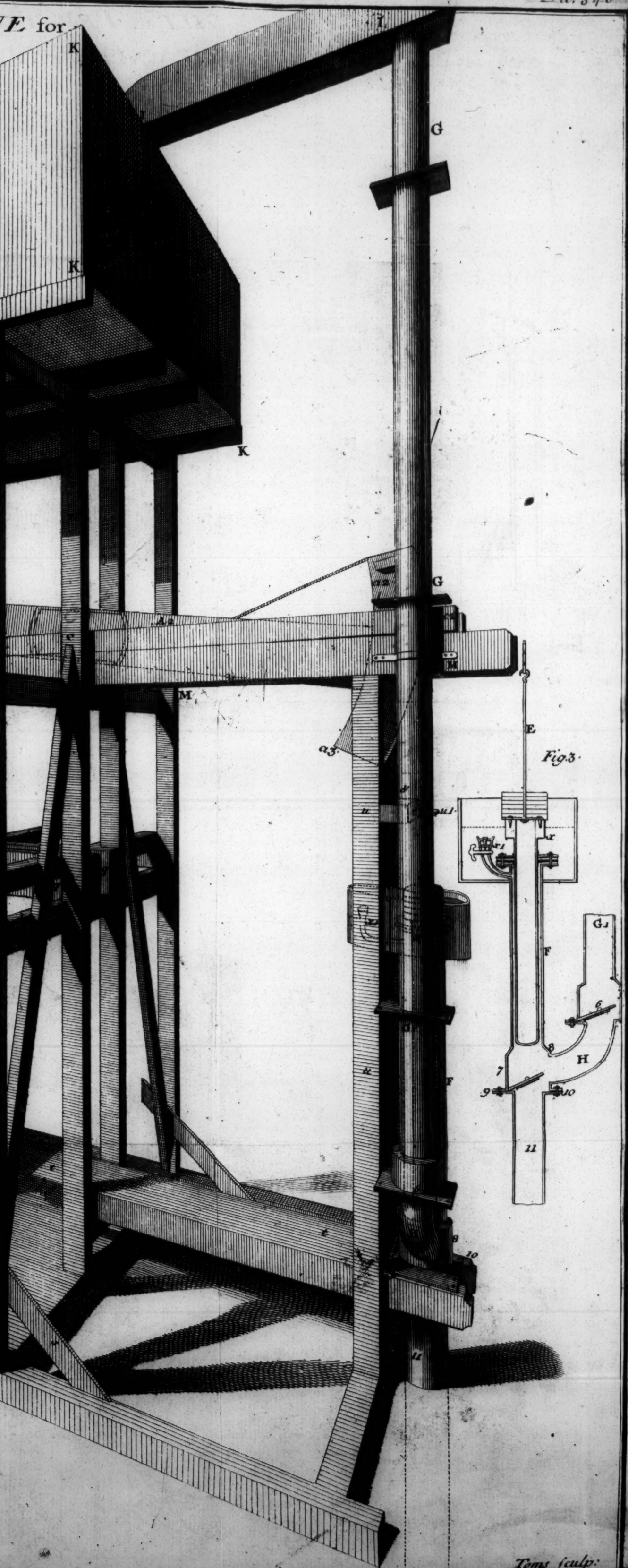


Fig 3.



and likewise very just, so as the Water may not descend by them when it is rais'd.

THE manner, by which the Hydraulick or Engine before mention'd, and its Effects, being thus explain'd, let us proceed to a curious Invention of *Hero Alexandrius*, which represents divers Birds, which shall sing diversely when an Owl turns towards them; and when the said Owl turns back again, they shall cease their Singing. *Vid. Plate 28. pag. 35.*

LET there be a Water-Wheel as A, which shall turn in a Case of Lead or Copper mark'd with C, which Case shall seem to keep the Water from scattering abroad and spoiling the Motion, and the Axle-tree of the said Wheel shall rest upon two round Holes, which shall be on the Sides of the said Case, and at the one End of the said Axle-tree which cometh thro' the said Case: There shall be a Pinion of eight Teeth mark'd with D, which shall turn a Barrel of 12 or 15 Inches; also there must be three Conveyances for the Wind mark'd with E F G, to which there are foldered 3 Cocks, whereof the Keys are made as M O, to the end that when the Barrel turns the Pins Q and R, they may make the said Conveyances open to let the Air into divers Whistles, the which shall make several different Tunes, according to the Fabrick of those Whistles, and the Disposition of the Pins and touches Q and R. And moreover, you may give a certain Motion to the Tails and Beaks of the Birds; if you put certain Strings to the Keys of the Cocks, as the Figure declares.

As concerning the Motion of the Owl, which turns forwards and backwards in a certain space of Time, it may be seen by the turning the Vessel X, and the Leaver 3 and 4, where is the Counterpoise 8; for this Vessel descends when full, and makes the Counterpoise to rise, and the Pin of the Leaver stops the Barrel, by the Means of the Pin marked 6, which is at the End thereof; and so the Birds cease their singing: Then when the Owl shall be towards them; and when the Vessel X is void, she shall turn again by the Means of the Counterpoise, and the Barrel shall begin to turn, as is demonstrable by the Figure.

A pretty Conceit of this Kind, where a Bird is taught to whistle, by the Fall of Water, is in an ancient Grotto at *Ainstone*, near the late Duke of *Shrewsbury's* in *Oxfordshire*, an Account of which you have in Dr. *Plott's* Natural History of that County, which was made to warble out its Sound by the Cadence of the Water; and innumerable other Inventions of that Kind might be contriv'd, too long for me to insert in this Place.

THE two last Machines I shall exhibit, are those by which you may make a pair of Organs found by the Means of Water, and the other one, whereby Organs, or any other Trumpet-like Instrument or Instruments shall sound, when the Sun shall be rising towards its Meridian, without any other Principle of Motion, but the Heat of the Sun and the Water.

THE Musical Wheel mark'd A (*Plate 29. Page 350*) may be of 5 or 6 Foot Diameter, which shall be turn'd by a Pinion of eight Teeth, to the Axle-tree whereof there shall be fitted a Wheel of twenty four Teeth, which shall be turn'd upon a Pinion, on whose Axle-tree the Water-Wheel C is fasten'd; the Keys are mark'd with D, and the Place where the Pipes arise with E, and the Summer with F, the three Registers mark'd G H I, are different the one from the other. And to the intent that the Noise of the Motion may not be heard when the Pipes play, it is good that there be a Wall of a Foot thick between the Registers and the said Motion; the Conveyances of the Wind are of Copper, which coming from the Summer to the Registers, pass through the said Walls.

THE other Machine, (*vid. Plate 30. Page 350*) is a Vessel of Copper or Lead mark'd A, very close and folder'd on every Side, and let it have a Siphon mark'd with C, which may be so made, that the End which is in the Vessel be near the Bottom, and that the Height of the said Pipe or Siphon be near the Height of the said Vessel, then the other End shall come forth of the said Vessel, to run into the Vessel D.

AND to order it so, that the Sun may not heat the Vessel A, till some determin'd Time about Mid-day, as you shall desire, let there be a Tablet made to the said Vessel, of strong Lead or Copper, mark'd with B (as if it were a Cover of the said Vessel half lifted up) but well folder'd thereto, and let the Vessel be well environed with a small Wall of Brick, so as there may be only the Side before open to the Sun, which Side should be exactly plac'd towards the South.

IT is certain, this being well done, that the Sun shall not shine against the said Vessel, but at Noon, or such other determinate Time thenabouts, as you shall desire; and then the Rays shine against the Angle, which the Top of the Vessel makes with the Table B, and by that Means heats the Top of the said Vessel, and which shall make a Compression in the Vessel, so as that the Water shall run forth by the Pipe C; let there be also a great Vessel mark'd with F, into which the Water of the Spring or Pipe of Conduit, which

which is to make the Motion, runs continually, and at the Bottom of the said Vessel there is a Valve mark'd with G, at the lower End whereof, there is a Pipe with a Cock mark'd with H, which serves to temper the Course of Water which falls upon the Water Wheel which is below.

So when the Sun shall be any where near, or at the Meridian or Place, towards which you place the Box, his Rays shall shine against the Vessel A, which shall cause a Compression of the Water which is within, which shall run forth by the Pipe C, into the Vessel D, which being half shut, shall descend and open the Valve G, which being open, the Water of the Vessel F shall run upon the Water Wheel, and make the Musick Barrel turn, as hath been before shewn; and the Pins that are put upon the said Barrel, shall touch the Keys M, which being put down, shall open the Valves which are under the Summer X; and the Wind that shall be in the said Summer, shall make the Pipes of the Organs or Trumpets sound, which are above the Summer. Now Wind may be given to the said Summer, after two several Manners; that is to say, by a Reserve, which is fill'd with the Water which falls upon the Water Wheel, or by Bellows, which are raised by another Water-Wheel, which shall move when the Vessel D descends, and shall open also a Valve, as that which is mark'd with G: But because the Musick Instrument must stop just at the Point where it began (when the Musick Barrel hath made one Turn) to the end, that when it begins to sound another Tune, the Musick may be of a just Measure.

Now, to make it stop, you shall make a small Vessel of Copper mark'd with E, which shall have a small Hole at Bottom, and shall be so placed, that the Cord which holds it shall be fastened to a Ring near the Valve G, and the Water which shall fill the said Vessel, shall be conveyed by the Pipe mark'd with L; so as when the Valve G is opened, forthwith the Water shall run into the said Vessel; and when the Water of the Vessel F shall be a little abated, then it shall run no more into the Vessel E, which shall always empty the Water which is in it by the small Hole at the Bottom; and the Time that the said Vessel E empties, must be fitted to the Time which the Wheel requires to make one Turn; and the said Vessel being empty, the Valve G shall fall down again, because it ought to be made in a manner heavier than the two Vessels C and D when they are empty: And on the contrary, when one of the said Vessels is full, that they may be heavier than the said Valve: And as concerning the Vessel D, it is necessary that it empties rather than E; because it need not keep so exact a Measure as E.

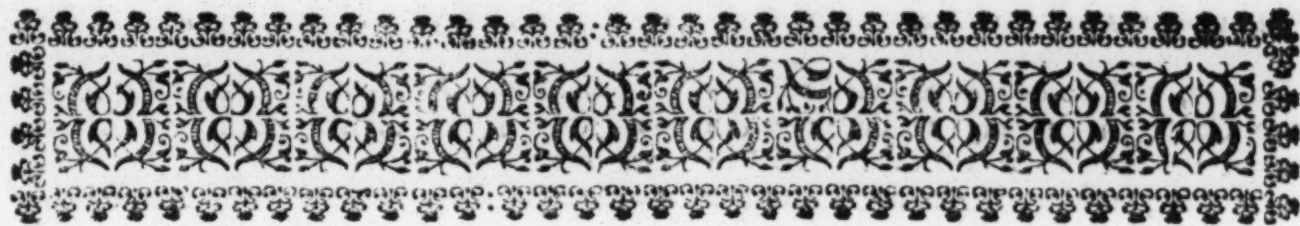
AND here may be seen likewise how it empties when it is half full of the Water which descends by the Pipe C, then it draws down itself, and that mark'd with E also; because it is heavier than G at the same Instant that G opens, and the Water descends upon the Wheel, and into the two Vessels; and when D is full, then the Vessel turns the Top downwards and empties; and in the same Time the Water of the Vessel F abates, and is lower than the Height of the Pipe at D, the Water shall run in no more, but the End of the Pipe L must be something lower than that of D, to the end that the Water may there run longer: It now remains to shew how the Pipe A is fill'd again with Water.

THEREFORE let there be a Pipe put with a small Valve under the said Vessel; and after that the Heat of the Sun has made the Compression, and that one Part of the Water of the said Vessel shall be run out after the Sun has passed the said Vessel, to fill again by the Valve, as has been before taught.

WHAT I have to add more to this Chapter, is to acquaint my Reader, that what I have laid down before, is taken either verbatim from *De Caus*, and other curious Authors, who have wrote on this Subject, and to introduce a Design, which I am told is in great Esteem in *Italy*, I mean the Organ, which is play'd by a Water Fall from the Top of a high Rock, (*Vid. Plate 59. or 60. Page 352*) which is, I think, in the Gardens of the Family of *Este* at *Tivoli*, leaving this so curious a Piece of Hydraulicks to the further Improvement of the Gentlemen whose Genius's lead them to the Seraphick Entertainments of Musick; in which I must own my self not well acquainted.

The End of the Third BOOK.

NOTES



NOTES on Book III.

*Of Engines for raising of Water, quenching of Fire, &c.
as contrived by several Engineers about LONDON.*



H A T I might finish this Book to the best Advantage for the Publick I can, I thought it would not be unacceptable to my Readers, especially those who live far in the Country, to insert the following Accounts of Engines.

I know in Engine-Work (as it is in most other Arts and Sciences) every particular Artist has his Friends and Favourites, who are always very diligent in crying down the Performances of others, and exalting that of their Friends; but as what I write, is rather calculated for the Publick Good, than for any private Advantage of my own; I am resolv'd to keep an exact Neutrality amongst these Gentlemen, and to give the Account verbatim, of every one of them (at least those which have come to my hands) a Place in this Undertaking, beginning with the Description of that which first came to Hand, I mean that of Mr. Fowke in *Nightingale Lane* in *Wapping*, who makes all constant stream'd Engines for extinguishing Fire, &c.

I. CONSTANT stream'd Engines for extinguishing Fires, the large Sizes play two Streams at once, being the first and only of their Kind, and does the Office of two Engines, and so contrived, as to be drawn

through, and (if occasion requires) work'd in a Passage three Feet wide, which no other can, and will feed themselves by a sucking Pipe. Their Movements are easy and natural, having a perpendicular Stroke, and is without either Rack, Wheel, Chain or Crank, whereby the Friction is lessened more than any others, and consequently requires less Strength, are more useful, and less liable to Disorder and Decay, and much cheaper than any other; and therefore are by judicious Persons esteemed preferable to all others. By screwing a Pipe they water Gardens, dispersing the Particles of Water for about 14 Yards square, like small Rain. The four largest Sizes run on Wheels, and the other two carried by two Men like a Chair. The Number of Sizes, Quantities of Water and Distance delivered with their Prices as below.

II. ENGINES which will work either by Water, Wind, Horse or Men, and so contrived, that either may work at a time, or be assistant to each other, whereby large Quantities of Water may be raised, so that if the Height, Distance and Quantity required be known, the Expence and Strength may be calculated so as to serve Cities, Towns, Noblemen and Gentlemen's Seats and Fountains, Brewers, Distillers, Dyers, and for draining of Lands, Ponds, and Mines of Lead, Coal, &c.

III. PUMPS

352 *An Introduction to a General System*

III. PUMPS which may be work'd by one Man, for raising Water out of any Well, upwards of 120 Feet deep, sufficient for the Service of any private House or Family, and so contrived that by turning a Cock, may supply a Cistern at the Top of the House, or a bathing Vessel in any Room; and by screwing a Leather Pipe the Water may be convey'd either up Stairs, or in at a Window, in Case of any Fire.

IV. ALL manner of Fancies in Fountains.

SPECIMENS now in Practice, viz. One made for Mr. Moses Hart at Isleworth, whereby 85 Barrels of Water in about the Space of half an Hour are thrown into a Cistern to the Top of his House in a constant Stream, and with great Velocity, from a River 540 Feet distant, and about 40 Feet perpendicular. Another at Deptford, for the Service of a Distil-House near the King's Yard, which will raise 150 Barrels of Water in less than an Hour, about 30 Feet perpendicular, with the like Stream and Force, and at the same Time (as Occa-

sion requires) does the Office of another Engine to raise Wash and Worts considerably higher; both Engines are performed with Ease by one Horse.

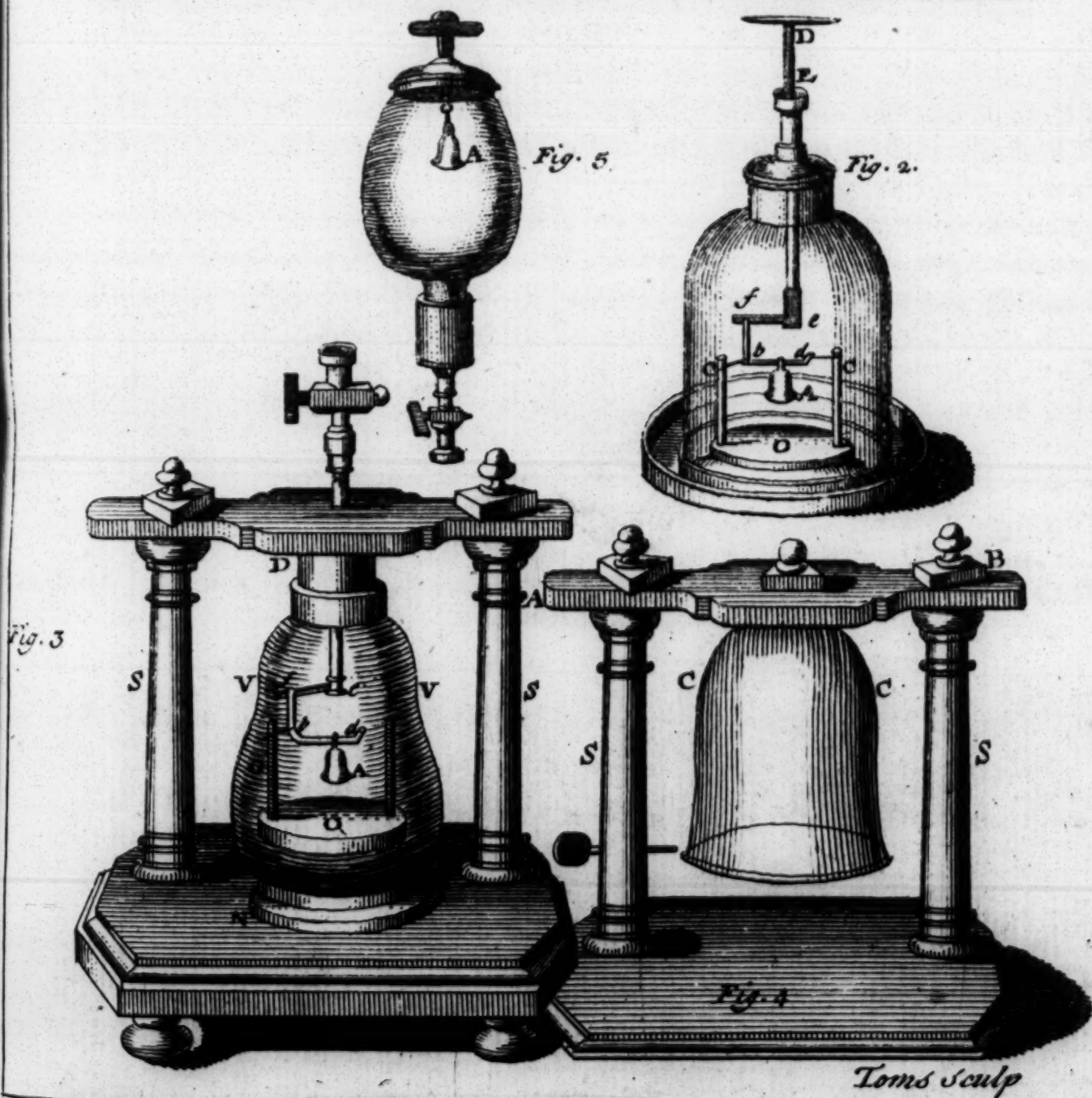
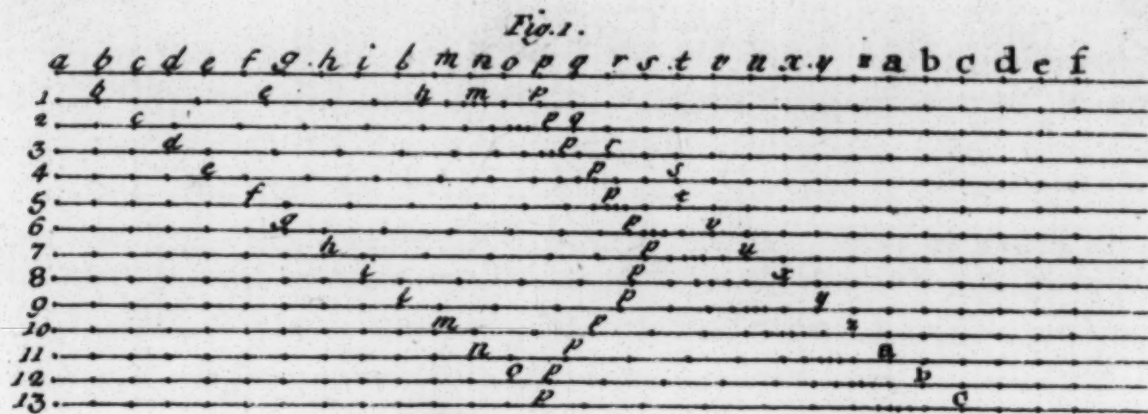
Also another made for Esquire Savill, near Sir John Eyles at Rufford, worked by two Men, that raises Water in the same constant Manner, through a Bore near two Inches Diameter, 360 Yards Distance, and 42 Feet perpendicular. With several other useful Engines, too tedious to mention.

The Encouragement given by the Honourable Board of His Majesty's Victualling-Office, South-Sea-Company, and other Honourable Persons, preferring their Fire-Engines to any others; and the Satisfaction given to the Gentlemen before mentioned, sufficiently shews their Excellency. And for the Satisfaction of any who shall be desirous of having Engines for the Services aforesaid, by sending a Line to Mr. Fowke in Nightingale Lane, Wapping, such Person shall be attended and made sensible, whether what he intends to have performed is feasible, before he is at any Expence.

Sizes.	Gallons of Water delivered in a Minute.	At what Number of Yards distant.	Prices with sucking Pipes.	40 Feet of Leather Pipes, with a Pair of Brass-Screws.
1ft.	40	27	14	l. s. d. 02 12 06
2d.	50	31	20	20 16 00
3d.	70	36	30	03 6 00
4th.	100	40	40	03 15 00
5th.	160	43	50	04 4 00
6th.	180	45	60	04 10 00

THE next Artist's Account I produce, is that of Mr. Richard Newsham of Cloth Fair, who makes the most useful, substantial, and convenient Engines for quenching Fires, &c.

Richard



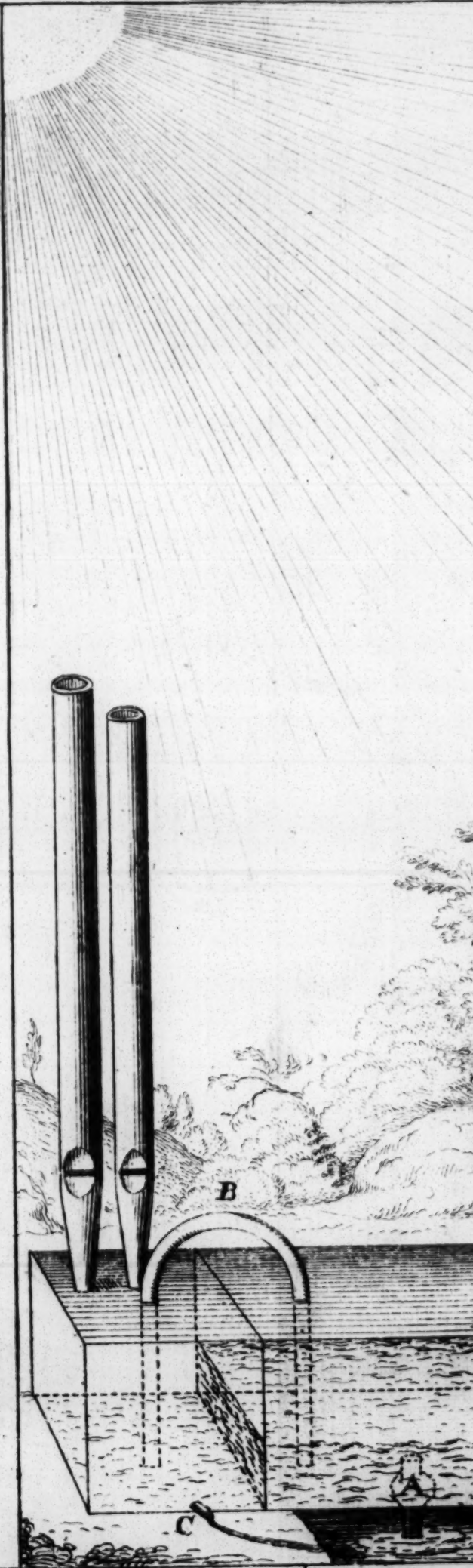
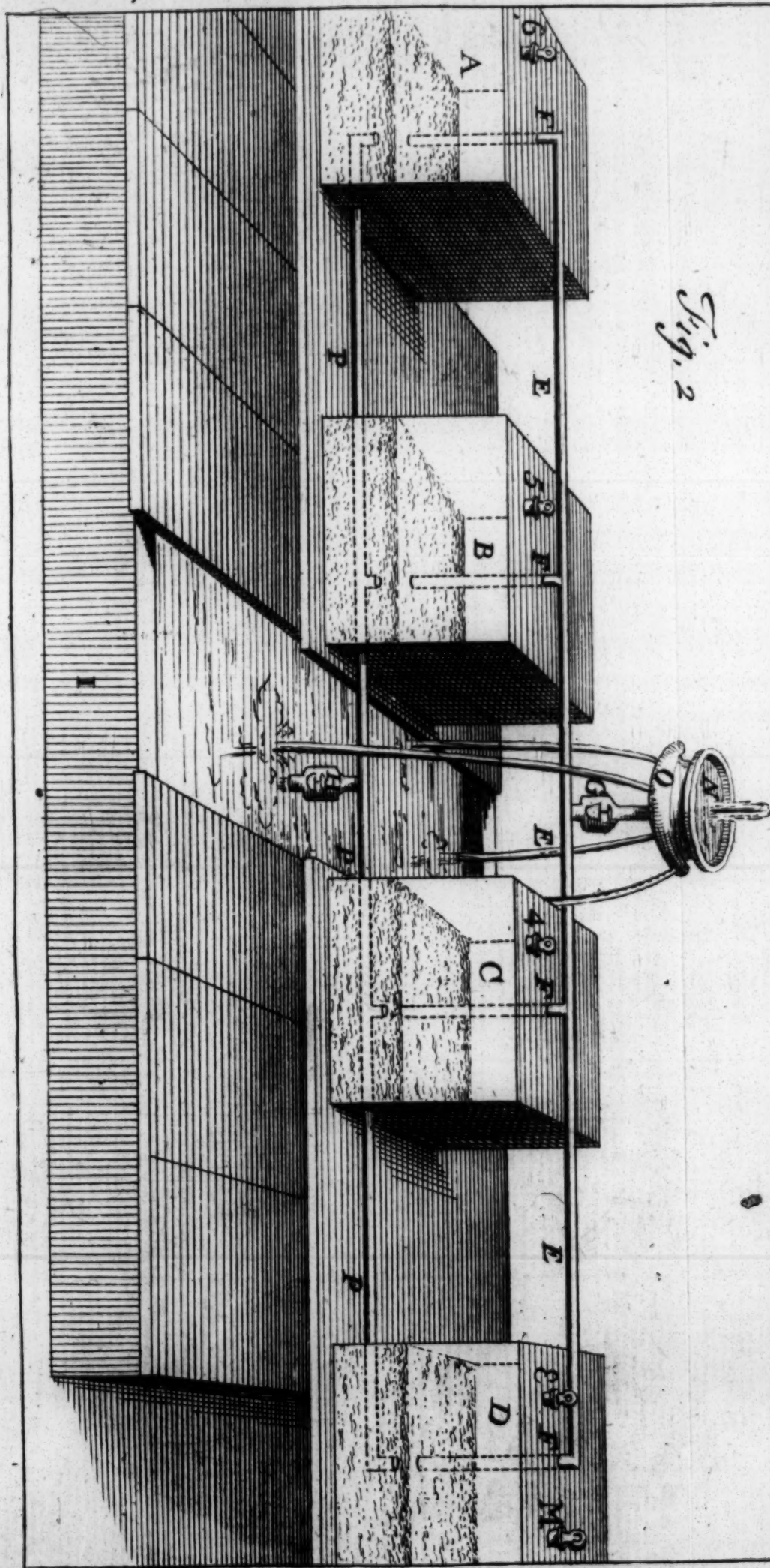
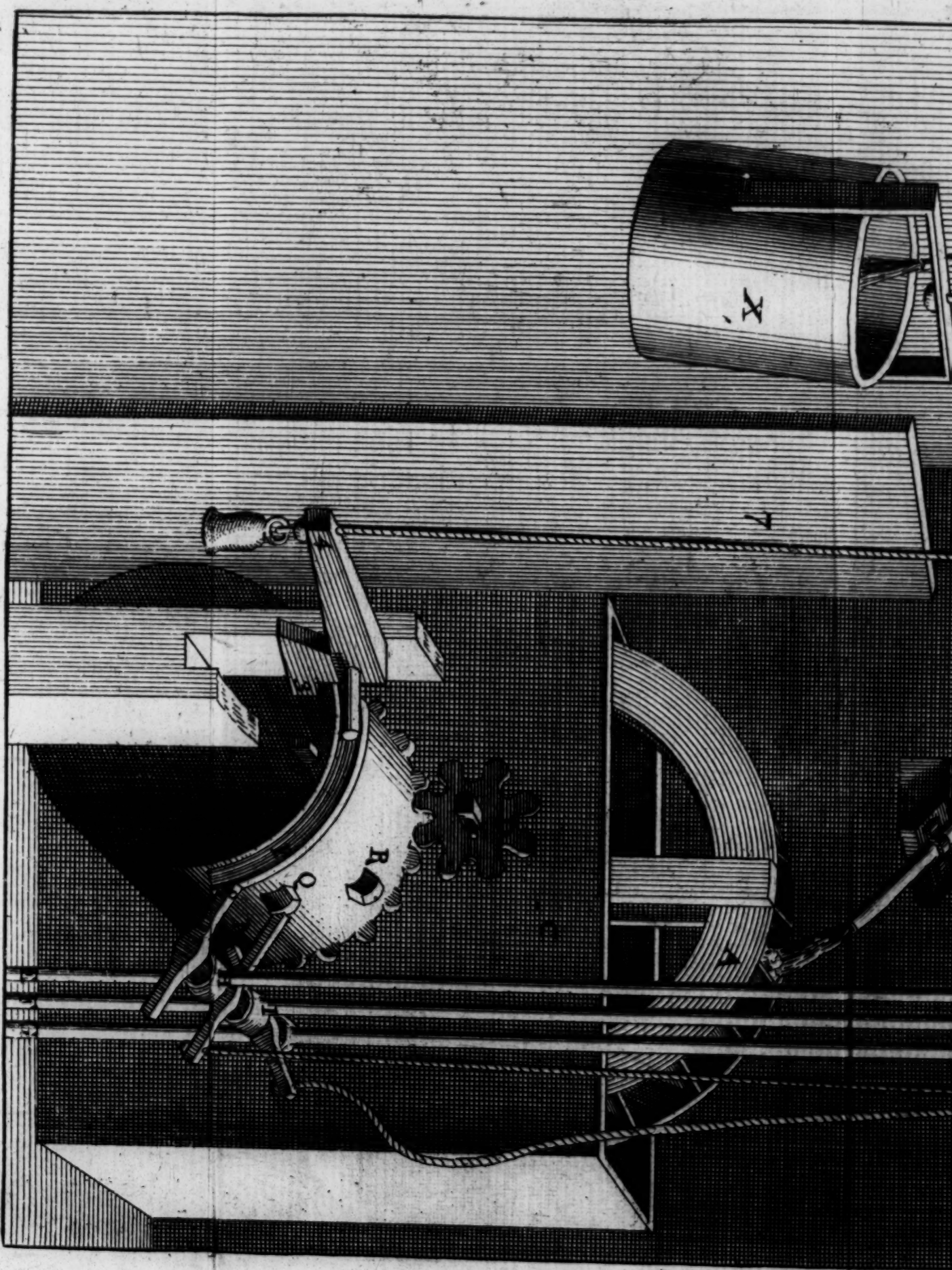


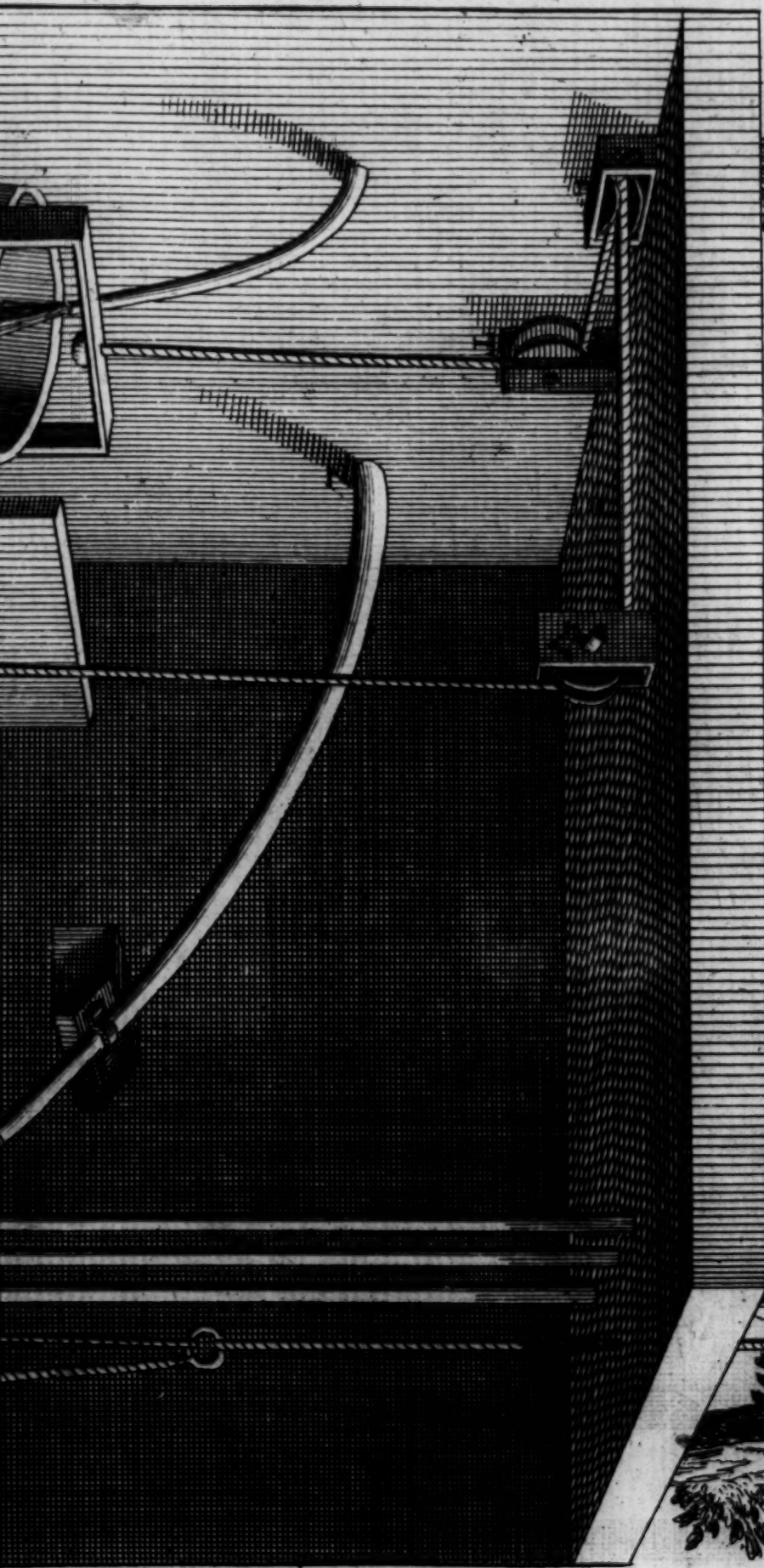
Fig: 1

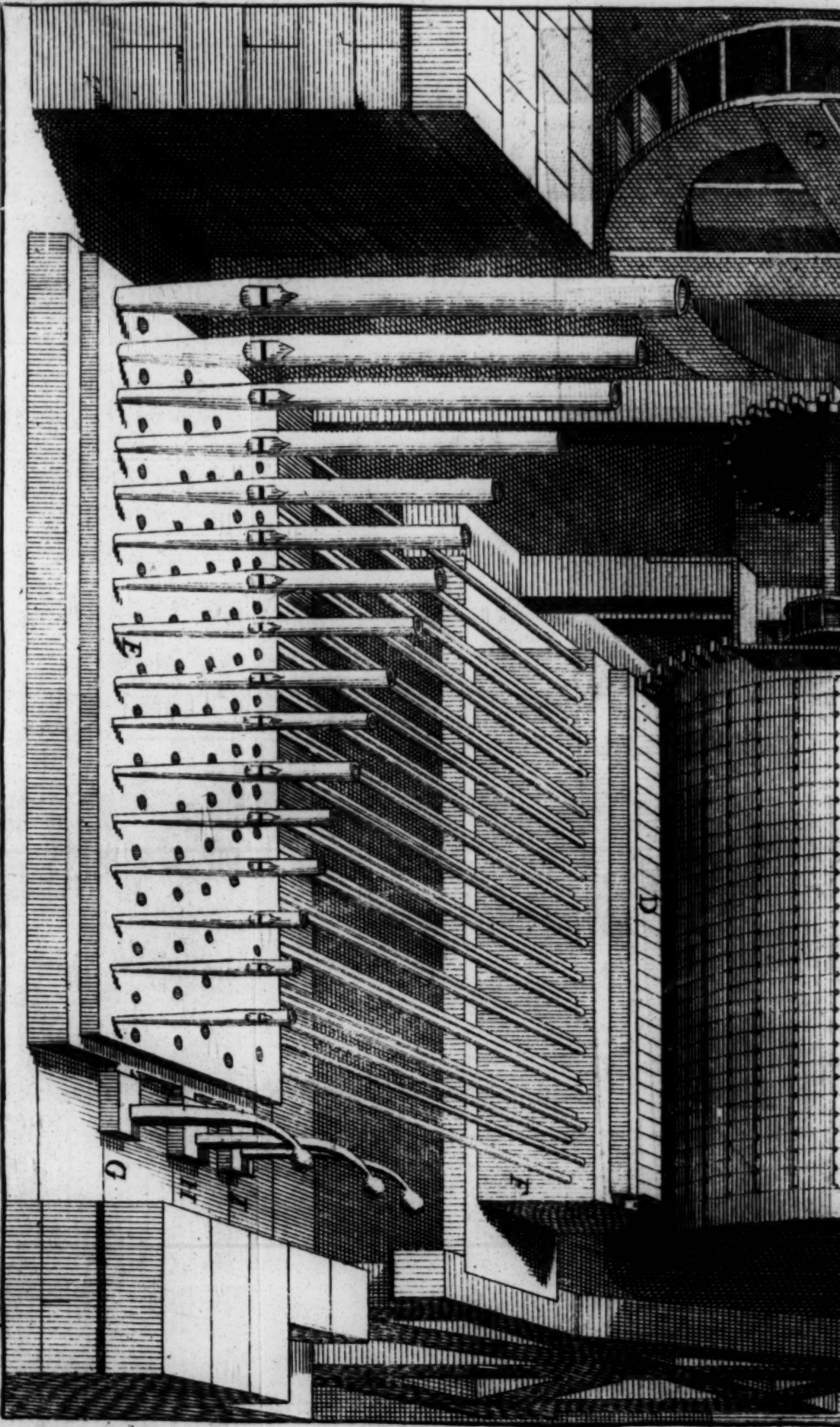


Toms Sculp



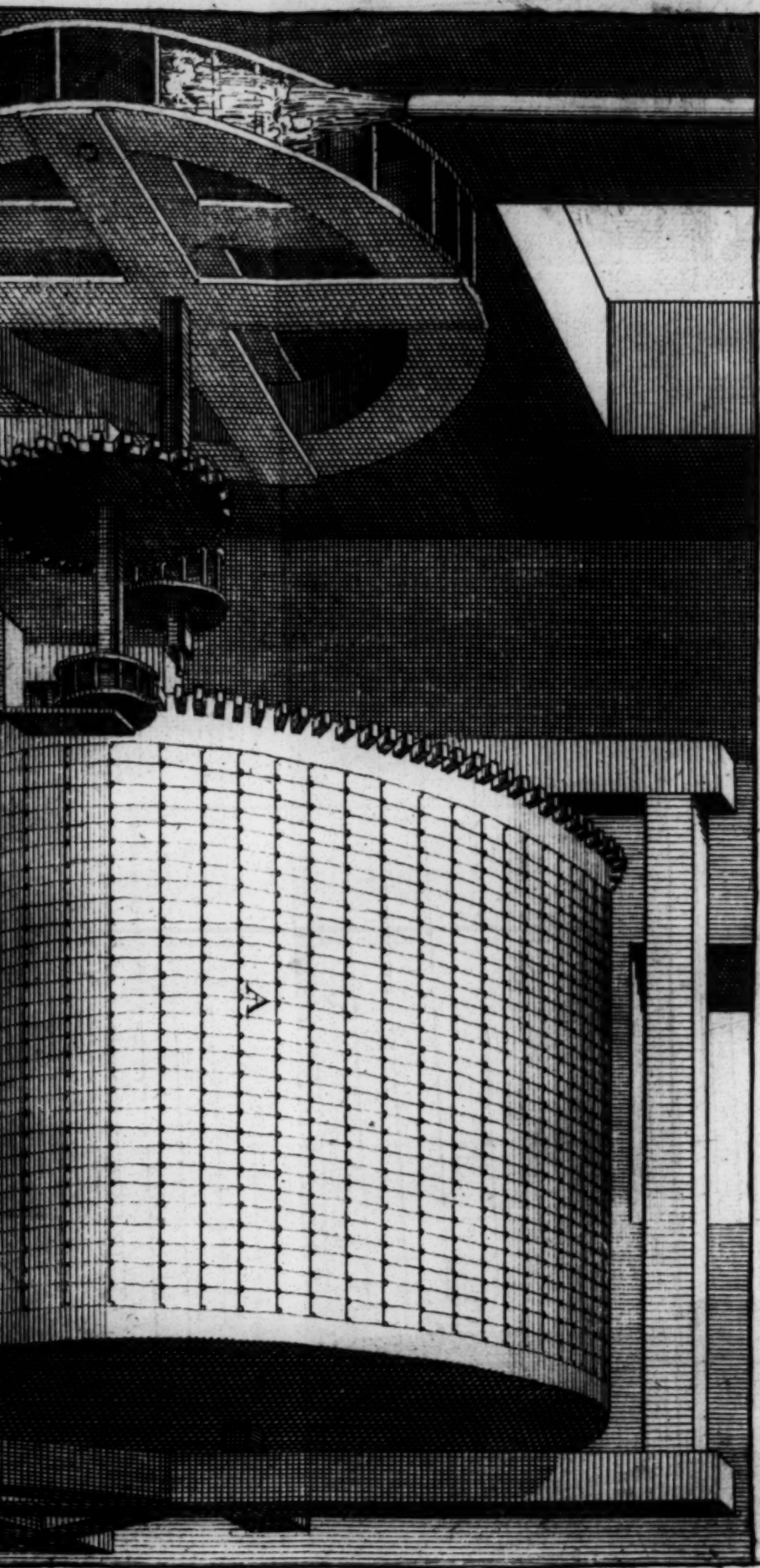
Toms & Co.



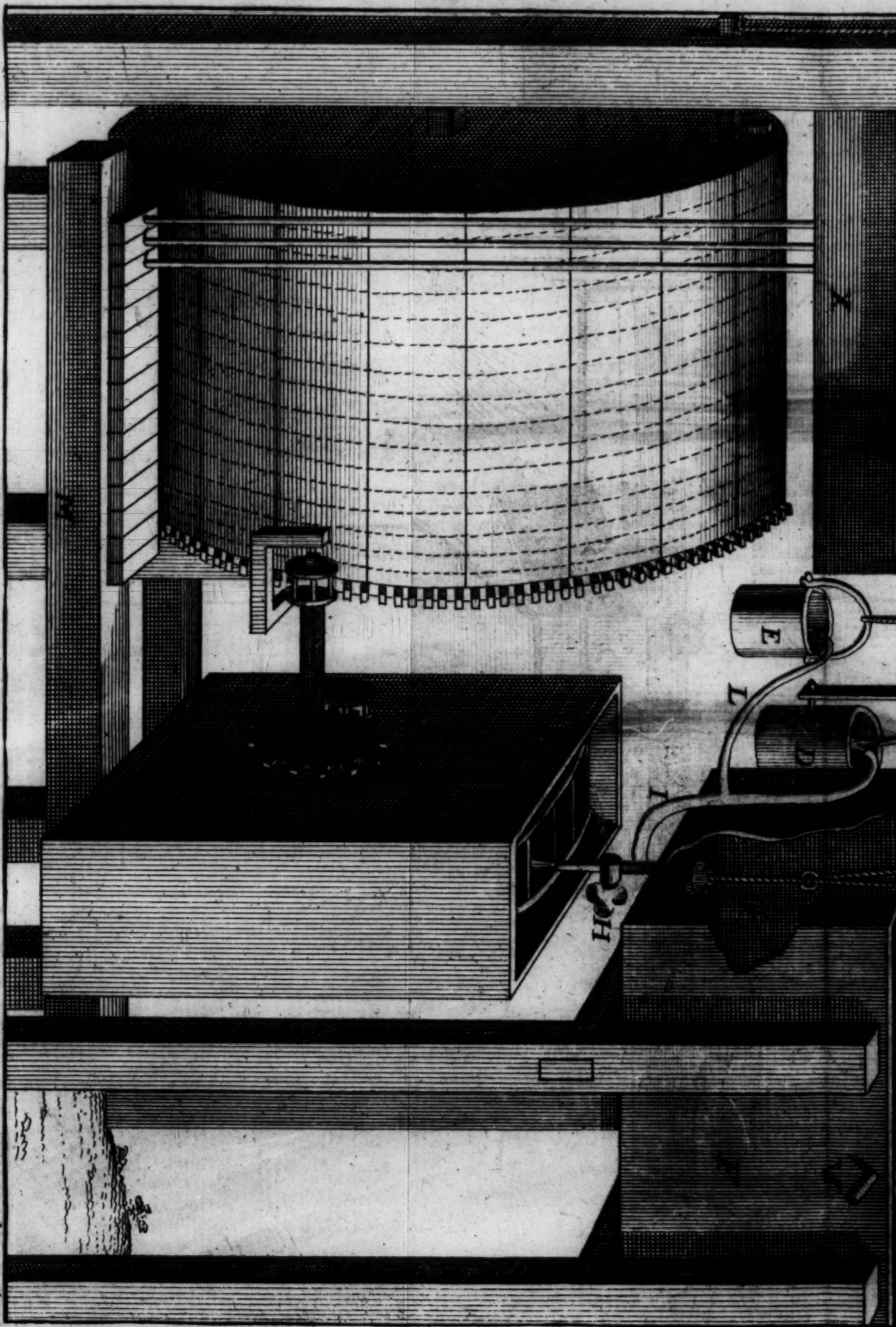


Tom's sculp

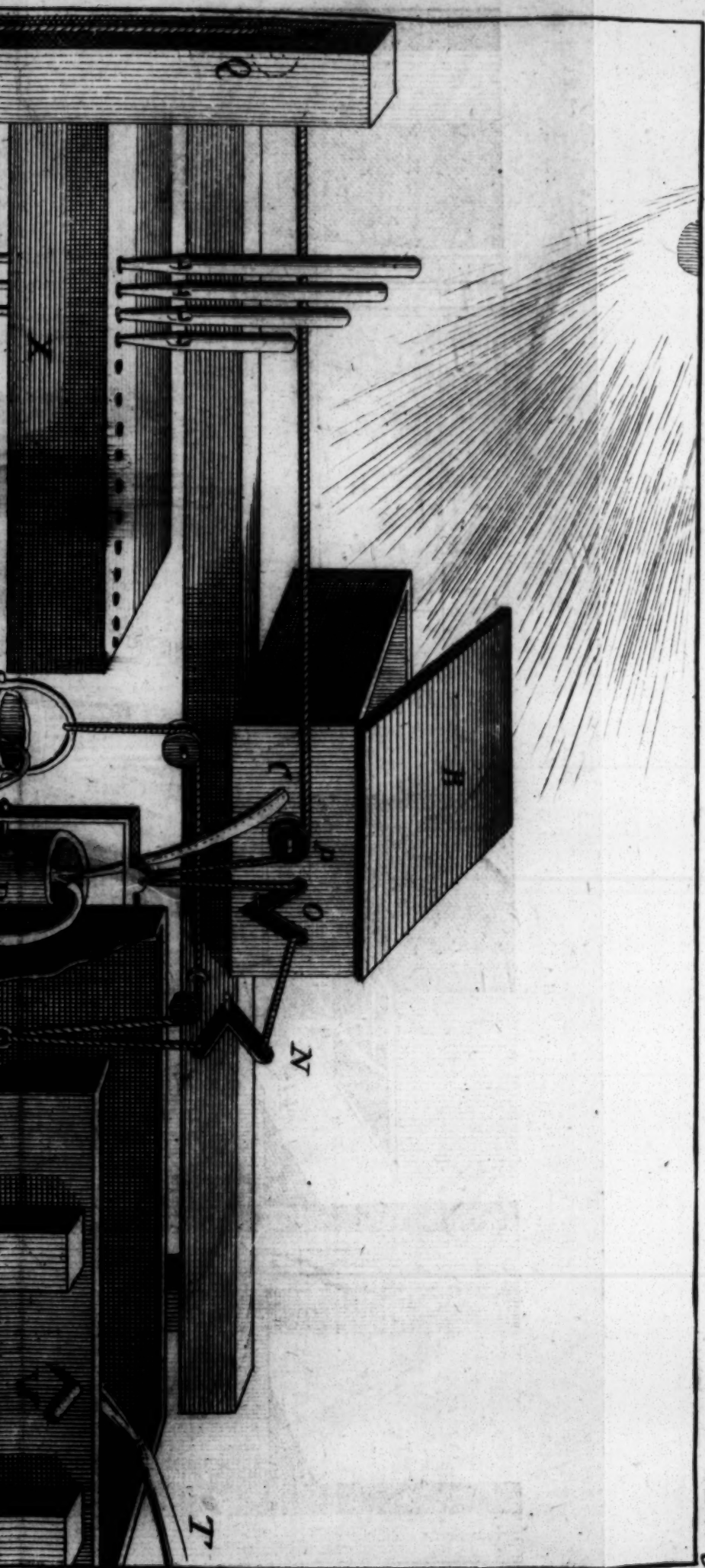
Plate 29

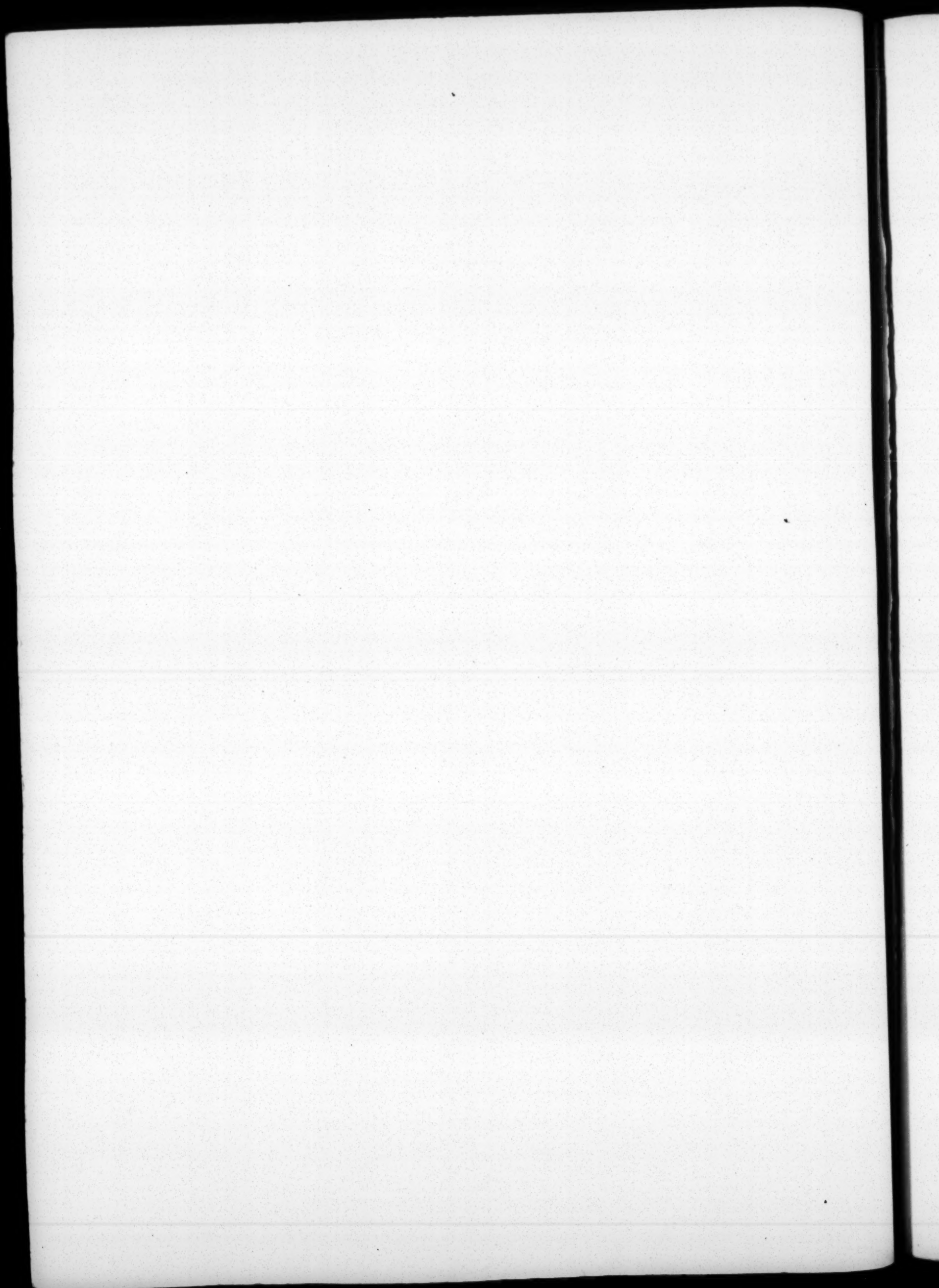


Pa. 352



J. J. Smith





Notes on Book III.

I

Richard Newsham of Cloth-Fair, London, Engineer,

MAKES the most *useful, substantial, and convenient Engines* for quenching Fires, which carries continual Streams with great Force. He hath play'd several of them before his Majesty, and the Nobility at St. James's, with so general an Approbation, that the largest was at the same time ordered for the Use of that Royal Palace: And as a further Encouragement (to prevent others from making the same Sort, or any Imitation thereof) his Majesty has since been graciously pleas'd to grant him his *second Letters Patent*, for the better securing his Property in *this*, and several other Inventions for raising Water from any Depth, to any Height required.

THE largest Engine will go through a Passage about three Foot wide, in complete working Order, without taking off, or putting on any thing: And may be *work'd with ten Men in the said Passage*. One Man can quickly, and with Ease, move the largest Size about, in the Compass it stands in: And is to be play'd without rocking, upon any uneven Ground, with Hands and Feet, or Hands only, which cannot be parallel'd by any other Sort whatsoever. There is *Conveniency* for above 20 Men to apply their full Strength, and yet reserve both Ends of the Cistern clear from Incumbrance, that others at the same time may be pouring in Water, which drains through large Copper Strainers. The Staves that are fixed through the Leavers, along the Sides of the Engine, for the Men to work by, though very light, as alternate Motions with quick Returns require; yet will not spring and lose Time the least: But the Staves of such Engines as are wrought at the Ends of the Cistern, will spring or break, if they be of such a Length as is necessary for a large Engine, when a considerable Power is apply'd: And cannot be fix'd fast, because they must at all Times be taken out, before That Engine can go through a Passage. The playing two

Streams at once, do neither issue a greater Quantity of Water, nor is it new, or so useful, there having been of the like Sort at the Steel-yard, and other Places, 30 or 40 Years; and the Water being divided, the Distance and Force are accordingly lessen'd thereby: That Way of working not becoming more publick, is a visible Proof, that it doth not answer; for with a very small Addition, any Engine will do the same.

THERE is a Mistake very common among such as are not well acquainted with the Laws of Nature, and the Effects of Mechanical Powers, who imagine, that the more Purchase the Leavers have upon the Forcers in the Barrels (without any Regard to Time) the greater the Performance, both as to Length of the Stream, and Quantity of Water deliver'd; but 'tis well known, that Notion is wrong; for the greater the Purchase is, by applying the operating Power, more distant from the Centre, the slower will the Motion of the Forcers be; which is consistent with all Mechanical Effects; thus, What is gain'd by the Power, is lost in Time.

THOSE who pretend to make the Forcers work in the Barrels, with a perpendicular Stroke, without Rack, Wheels, Chains, Crank, Pully, or the like, by any kind of contrived Leavers, or circular Motion whatsoever, with less Friction, than if guided and work'd by Wheel and Chains, (which of all Methods is the best,) do only discover their Ignorance; they may as reasonably argue, that a great Weight can be dragg'd upon a Sledge, with as little Strength, as if drawn upon Wheels.

THE approv'd Duration of those Chains both from Water and Rust, has been sufficiently experienc'd for some Years, in several Parts of this and other Kingdoms; but to instance some Places at Home, particularly at the Hand-in-Hand, and other Assurance Offices, whose Business it is to be first and last at every Fire that happens in

the Cities of *London* and *Westminster*, and the *Suburbs* thereof; who consequently with much using, must have thoroughly tried them. As to the *Treddles*, on which the Men work with their Feet, there is no Method so powerful, with the like *Velocity* or *Quickness*, and more natural and safe for the Men: Great Attempts have been made to exceed, but none yet could equal this Sort; the fifth Size of which hath play'd above the Grasshopper upon the *Royal Exchange*; which is upwards of 55 Yards high, and this in the Presence of many thousand Spectators.

Those with Suction feed themselves with Water from a Canal, Pond, Well, &c. or out of their own Cisterns, by the Turn of a Cock, without interrupting the Stream. They are far less liable to Disorder, much more durable in all their Parts, than any extant, and play off large Quantities of Water at the Distances under-mentioned, either from the Engine, or a Leather Pipe, or Pipes of any Length requir'd; (the Screws all fitting each other) This the cumbersome squirting-Engines, which take up four times more Room, cannot perform; neither do they throw one fourth Part of their Water in the Fire, at the like Distances, but lose it by the Way; nor can they use Leather-Pipe with them to much Advan-

tage, whatever Necessity there may be for it.

THE five large Sizes go upon Wheels, well box'd with Brass, fitted to strong Iron Axles, and the other is to be carried like a Chair. — Their Performances are as follow, and the Prices fix'd so, as to induce the Nobility, the Commons, Cities, Boroughs, Corporations, Towns, Colleges, Hospitals, Companies-Halls, Parishes, the Gentry, and others, who have not furnished themselves therewith, to become acquainted with this useful Invention, for their Defence against desolating Fires.

THESE Engines will also, by putting the Fan upon the Branch, water Gardens like unto Rain.

HE makes some smaller Engines, from 6 l. to 17 l. Value, and Machines for emptying Ponds to raise Water, Hot-Worts, &c. and Water-Works for any Purpose, to be work'd by Water, Horse, or Man; or by Wind, on a constant Speed, tho' it blow unequally, which of themselves always keep their Sails to the Wind: Also Fountains, that will play Columns of Water 4 Inches Diameter, 40 Foot high, with one 10th Part of the Water, and Power to force it, as is required in other Jets of the like Size and Height.

Number of Sizes.	What Quantity of Water the Cisterns hold in Gallons.	Quantity discharged per Minute in Gallons.	At what Number of Yards Distance.	Price without Suction.	Price with Suction, and 6 Foot of Sucking-Pipe included.	Price of the Leather-Pipes, each Pipe 40 Foot long, with a Pair of Brass Screws included.	
1ft.	40	60	33	17 l.	20 l.	2 l.	18 s.
2d.	75	75	35	26	30	3	3
3d.	95	100	40	30	35	3	5
4th.	125	125	45	35	40	3	7
5th.	176	160	48	45	50	3	17
6th.	185	190	50	55	60	5	

POSTSCRIPT by way of Notes on Book III. relating to the Raising of Water in Pumps.

TO compleat this Collection of Hydraulicks, I add, by way of Postscript, an Observation which I have long made concerning the Practitioners in the Art of Pump-work, who differ very largely from each other in their Opinion, relating to the proper Length or Fall of Pistons in Pumps; those who are for making the Stroke long, viz. 3, 4, or 5 Foot, or sometimes more, urge the Necessity there is to force up large Quantities of Water to great Heights, and say, that if there is not such a Thrust, the Water will recede backwards again, and not rise up with that Uniformity which is requisite in Works that go continually; but others are of a different Opinion, and, amongst them, Mr. Newsham of Cloth-Fair tells us in his printed Proposals, That *what is got in Purchase is lost in Time*; and indeed I cannot but be of the same Opinion as this laborious Engineer is of, and think, that where there are 3 or 4 Leavers constantly at Work, there is no Occasion for long Strokes, unless it be where there is only a single Piston, as is in the *Tork-Buildings Engine*; and there indeed a 6 Foot Stroke is necessary, in order to the giving the Water in the Pipes its full Force.

Mariotte, Page 105. of his *Hydrostaticks* (English Edition) makes use of an Algebraical Calculation for the raising of Water in the following Manner. Suppose, (says he) the Barrel to be 12 Foot above the Surface of the Water, that you would raise; and suppose that you have a mind to raise it to this Height of 12 Foot by one Stroke of the Piston, you must make this Analogy: As 20, the Complement of 12 Foot, is to 32; so is 12 Foot of common Air to a 4th Proportional; this 4th Proportional will be $19\frac{1}{3}$, which shews that the Barrel of the Pump must be pretty long to raise the Piston $19\frac{1}{3}$ Foot $\frac{1}{3}$ above the 12 Foot, in order to raise the Water 12 Foot,

by only one Stroke of the Piston; but if the Play or Stroke of the Piston were limited to 2 Foot, you must say; As $32 - A$ is to 32, so is $12 - A$ to $14 - A$. The first Term is the Complement of the unknown Height to which the Water will rise, to 32 Foot of Water; which is the Weight of the Atmosphere: The third Term is the 12 Foot *minus* that Height, and the Fourth is the 2 Foot that the Piston rises, join'd to 12 Foot *minus* the same Height. Now the Product of $14 - A$, by $32 - A$, is $448 - 46A + AA$, and the Product of the two middle Terms is $384 - 32A$; the Equation being reduc'd, there will be an Equality betwixt AA and $14A - 64$; and because 64 cannot be taken from 49 the Square of 7, which is half the Roots, 'tis a Sign, that in continuing to pump, at several times you may raise the Water up to the Piston; and to know how far it will rise the first Stroke, you must suppose that the Piston is risen 2 Foot; there will be an uniform Barrel of 14 Foot; and according to the Rules laid down in his Essay upon Logick, and his Treatise of the Nature of Air, which makes this Calculation. The enclos'd Air was 12 Foot; $12\text{ Foot} + A$ is to A , as 32 to $2 - A$; the Equation being reduc'd, you will find that AA will be equal to $24 - 42A$; and at last, that the Value of the Root will be a little less than $\frac{4}{3}$; which being taken from 2, there will remain $1\frac{2}{3}$ and a little more; and consequently the Water will by the first Stroke of the Piston rise but one Foot $\frac{2}{3}$, and a little more.

If you had suppos'd the Play of the Piston to be one Foot, you might know by the same Calculation how high the Water would rise by the first Stroke of the Piston; and if you would know to what Height it may rise after several Strokes, you must say, As $32 - A$ is to 32, so $12 - A$ is to $13 - A$; the Equation being reduc'd, you will find $13A = 32$ equal to A

to A A. The Square of $6\frac{1}{2}$ the Half of the Root is $42\frac{1}{4}$; from which subtracting 32, there remains $10\frac{1}{4}$, the Root of which is $3\frac{1}{4}$ a little less: Take that from $6\frac{1}{2}$, and there remains 3 and $\frac{2}{4}$; add that to $6\frac{1}{2}$, and it will make $9\frac{1}{2}$; and these $3\frac{1}{4}$ and $\frac{1}{2}$ will be the two Roots; which shews that the Water can never rise when the Barrel is empty, above 3 foot $\frac{2}{4}$ and a little more, tho' you play the Piston as long as you please; but if you had fill'd the Barrel 9 Foot $\frac{1}{4}$, you might make the Water rise 12 Foot compleat by several Strokes of the Piston.

LET us suppose now that the Barrel is 14 Foot up to the Piston, and that the Stroke of the Piston is 2 Foot; $32 - A$ will be to 32, as $14 - A$ to $16 - A$. To find the Equation easily, you must multiply 32 by 2, the Difference of 14 and 16: The Product is 64 for the absolute Number, and that of $16 A$, will be the Number of the Roots, and A A will be equal to $16 A - 64$; the Square of half the Root is 64; from whence subtracting 64, there remains 0, whose Root is 0, which being taken from and added to 8, still makes 8; which shews that there is but one Root, and that the Water can't rise above 8 Foot; but if you make the Piston play ever so little higher than 2 Foot, the Water will rise 14 Foot. The Analogy is easy; for the Piston being raised 2 Foot, the Barrel will be 16 Foot, and that Water being at 8 Foot, there will remain 6 Foot of Air; but 32 is to 24 the Complement of 8 Foot to 32, as 8 Foot of rarified Air to 6 Foot of common Air; then the Water will raise no higher than 8 Foot, if the Piston plays but 2 Foot.

THENCE you see, that to draw up Water to a considerable Height, as 20 Foot, the Breadth of the Pump-Barrel must be diminish'd, and a sufficient Space must be allow'd for the Stroke of the Piston; for, supposing that the Surface of the Piston be 4 times broader than the Base of the Barrel, the rising of the Piston 1 Foot, will have the same Effect as if it rose 4, if the Diameter of the Piston were only equal to that of the Barrel; if then the Stroke be 2 Foot and a half, it will be the same as if it rose 6 Foot, and were of the same Breadth: Now the 4 Terms of Equation

being $32 - A$; 32 , $20 - A$, $26 - A$, there will be 6 times 32, viz. 192 for one Term of the Equation, and 26 A for the other, according to what has been said; there will be then A A equal to $26 A - 192$; the Square of half the Roots is 169 less than 192; and consequently if you pump a long time, you may raise the Water 20 Foot.

IF in the Example above-mention'd, you take 8 Foot for the highest Term of the Water, when the Barrel is 14 Foot, and the Stroke of the Piston 2 Foot, 'tis easy to prove, that if you suppose 9 Foot of Water upon the Clack, it will continue to rise by the playing of the Piston 2 Foot; for there will remain 5 Foot of Air. Now there is a less Proportion betwixt 5 and 7, than there is betwixt 27, the Complement of 5 to 32, and 32, and consequently the Water will rise higher than 9 Foot. The Proportion will still be more unequal, if you take 10 or 11 Foot; and if you take 7 instead of 8 Foot, the Water will still rise, for there will remain 7 Foot of Air; now 25, the Complement of 7 to 32, is to 32 as 7 to $8\frac{2}{3}$; then if the Piston goes 2 Foot, it will raise the Water higher than 7 Foot; it will rise still more easily, if you pour in only 6 Foot of Water; for there will be 8 Foot of Air. Now the Complement 26 is to 32 as 8 to $9\frac{2}{3}$; then if instead of $9\frac{2}{3}$, which makes the *Equilibrium*, the Piston goes 10 Foot, it will make the Water rise still better than when it was at 7 Foot; and better still than when it is at 5 Foot, &c. If you would know what Play the Piston must have to raise the Water 30 Foot, you must take a Number a little greater than the half of 30, as 16, at which Point pretty near the Water, will rise with the greatest Difficulty; the Complement is 16, the Remainder of Air is 14; as 16 is to 32, so is 14 to 28. The Piston then must rise 14 Foot; or if the Barrel be 2 Inches Diameter, the Piston must be 7 Inches $\frac{1}{2}$; for the Square of $7\frac{1}{2}$ is $56\frac{1}{4}$, which is a little more than 14 times 4 the Square of 2 Inches; and then it will be sufficient that the Stroke of the Piston be one Foot; but as it is still more difficult at an Elevation of 18 Foot, the Piston must be 8 Inches Diameter, to raise the Water above 18 Foot, when its Stroke is but one Foot.

BOOK IV.



A N
INTRODUCTION
T O A
General S Y S T E M
O F
HYDROSTATICKS and HYDRAULICKS.

B O O K IV.

C H A P. XXX.

A General Introduction concerning the Coming-in of Water from Engines, or Springs, and the Expence thereof in Cascades and Fountains.

IT highly behoves all Persons that would have their Waterworks to succeed well, to make the exactest Calculations they possibly can, what Water their Engine or Spring will supply them withal; that so they may regulate the Extent of their Pipes of Conduct, Sheets, and Jets of Water, &c. since it would be a great Dissatisfaction and Reproach

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Reproach to the Owner of any Waterworks to have fine Grotto-Work, Cascades, and other Inventions of this Kind, and not to have Water to supply them withal.

BUT by this Supply I would not be understood to mean a continual Cadence or Current of Water, that being to be had but in few Places, except on low Grounds, where Rivers, at least Rivulets, have their Course: Nor can I readily subscribe to those that value no Cascade or Fountain, except they play continually, since that would be limiting Waterworks to a few Places only, and would be the debarring many a pleasant Situation of that which is one of the greatest Beauties of it; I mean that of fine Water, especially if to it be added the Cadence and Murmuring of Streams, in Grotto, Rock, Cascade, and Fountain-Works, which, tho' they do not play always, yet have their proper Times of Diversion, in all hot and sultry Weather, and in the Lawns and other intermediate Spaces of Woods, Groves, and other Places of Delight; and the Experience we daily have of the vast Quantities of Water that good Engines produce, (which when emptied into Reservoirs or Ponds, well clay'd, afford surprizing Quantities of Water, enough to supply not only Cities and Towns, but also large Basons of Water,) confirm what I offer on this Head.

NOW, for the better understanding this Art, it will be requisite that the Owner and Projector be rightly inform'd how many Inches of Water his Engine or Spring will give in a Minute, or an Hour, and consequently how great a Quantity in twenty four Hours; that so he may compute how wide his Cascades, Fountains, or his other Expences of Water that are required may be, and how long the Supply that arrives in twenty four Hours will play: One or two Hours, at most, in a Day, is generally supposed sufficient; and for the Thickness of Water over a Cascade, half an Inch is enough; and from Preliminaries so established, may also be readily calculated, how much such Cascades may be contracted and enlarged. To proceed to the Theory or Motion of Spouting Water, &c.

THE learned *Gravesende*, *Book II. Part 2. Cap. 8.* of his *Mathematical Elements of Natural Philosophy*, says, That a Liquid spouting vertically out of a Hole, arises up with that Celerity, with which it would come up to the upper Surface of the Liquid, yet it never comes up to that Height: Because the Velocity of a Liquid increases, when the Depth of the Hole below the Surface of the Liquid increases, in the same Ratio as the Celerity of the falling Body increases, when the Space gone through by the Fall increases; and it is remarkable, that in the Beginning their Velocities are equal;
for

for in a Liquid the upper Parts, as well as those in a Body, endeavour to descend by Gravity only.

Now the Celerity by which a Liquid ascends is diminish'd every Moment, and the Column of the spouting Liquid consists of Parts, which are moved to different Heights by different Celerities: All the Parts of a Column, which is every where of the same Thickness, are necessarily moved with the same Celerity; the said Column will be every where broader every Moment, as the Celerity of the Liquid is diminish'd, which arises from the Impulse of the Liquid following, and which, from the Nature of a Liquid, yields to every Impression, and is easily moved every Way; and by that Impression the Motion is retarded every where.

Secondly, This Motion is also diminish'd by the Liquid, because when it has lost all its Motion, it is hang'd up in the upper Part of the Column, and is sustained for a Moment by the Liquid that follows it, before it flows off on the Sides, which retards the Liquid that follows it, and that Retardation is communicated to the whole Column.

Thirdly, This Motion of the Liquid is also diminish'd by the Friction that is against the Sides of the Hole, which Friction is increased when the Liquid is brought through Pipes and Cocks: And, *lastly*, the Resistance of the Air stops the Motion of all Liquids; the first Cause cannot be corrected, but the second may, by somewhat inclining the Direction of the Liquid, (as by laying the Pipe on a Slope,) because every Liquid rises higher, and consequently gives more Water, if it be a little inclined, than if it spouts vertically. This Celerity, and consequently the Quantity of this Water, is likewise expedited by the Height of the Reservoir (or Impulse and Force of the Engine) from which it proceeds, as well as from the Largeness of the Apertures or Holes of the Adjutages and Pipes of Conduct, to which they are fastened, which causes the Water-Spouts to go the quicker; and the Expence of Water through the same Passage is according to the Proportion of the Celerity or Velocity (call it which you will) it has in flowing out; and this Expence (as *Marriotte* sets down, *Discourse III. Page 172.*) is according to the duplicate Ratio of the Diameters of the Holes, which he has demonstrated in the following Manner.

A B (*Fig. 1. Plate V.*) is a Plane with a round Hole bor'd in at *ef*; C D is another Plane bor'd with another Hole, though less, at *gh*; I L is a Cylinder passing through the Hole *ef* in a certain Time, as in two Seconds, according to an uniform Velocity; M N is another Cylinder of the same Length, but the Base much less,

which also passes entirely through the Hole $g b$ in two Seconds. It is manifest, that if the Diameter $E F$ of the Cylinder $I L$, which is equal to that of the Hole, be double the Diameter of $g b$, the great Cylinder will be four Times as big as the other, since they are to one another as their Bases, each of which is supposed to be equal to the Hole through which they pass: Now since they have the same Velocity, when the half of the great Cylinder is passed through, the half of the little one will also be gone through; and that which has passed of one and the other, will be always in the same Proportion of 4 to 1: Then if we suppose these Cylinders to be Water-Spouts that have the same Velocity, there will always spout four Times as much Water from the great Hole as from the little one, which is in a duplicate Proportion of the Diameters of the Holes; and just so in respect of other Proportions.

FROM which Maxim he draws the two following Experiments:

First, That a Reservoir, or Cistern, 12 Foot 4 Inches deep, yielded through an Hole, exactly of 3 Lines Diameter, 14 Pints in 61 Seconds and a half, or, in other Words, in one Minute, one Second and a half, if continually kept full, that the Height of Water might press upon it; and though exactly of 6 Lines, it will yield the same Quantity in 15 Seconds and a half, which is almost according to the duplicate Proportion of the Diameter; for it would have yielded 56 Pints and a half in about the Time of 62 Seconds.

Secondly, That a Reservoir of 24 Foot 5 Inches deep yielded through the same Hole of 3 Lines 14 Pints in 44 Seconds and a half; and in another Time in 45; and the Hole of 6 Lines yielded the same Quantity in 11 and almost 1 quarter; and having repeated the Experiment, it yielded it in 12 Minutes precisely.

FROM whence, as well as from innumerable other Experiments that might be produced, it appears, that the Expence of Water coming into, or going out from one Reservoir to another of equal Height, is in a duplicate Ratio of the Diameter of the Holes, the Diameter lying about seven Lines below the Surface of the Water; but when the Heights of the Water in the Reservoirs are different, the highest give more than the others in a subduplicate Ratio of the Heights, that is, as the least Height to the mean Proportional betwixt it and the great Height.

Torricelli, in his Treatise of the Motion of Water, (as *Marriotte* sets down, pag. 180.) has given a Demonstration, which seems *apropos* to the present Purpose; when he says, That if a Reservoir $A B C D$, has a little Hole of four or five Lines at the Bottom at E , (*Fig. 72. Plate 5.*) and the Water being at the Height of the Line $A B$,

A B, may run out in 10 Minutes without pouring in any more, in its Descent it will pass through unequal Spaces in equal Times: so that if you divide the Line BC into 100 equal Parts, during the first of these Minutes, it will descend 19 of these Parts, during the Second 17, during the Third 15, &c. and so on, according to a Series of odd Numbers, down to an Unit; so that the last Part will go out in the last of 10 Minutes.

THE Reason of which is founded on what is before set down, *viz.* That the Velocities of Running Water are in a subduplicate Ratio of their Heights; and consequently, that they are to each other as the Ordinates of a Parabola A B C, beginning at the greatest A B, and ending at the Point C; which causes the Spaces passed through in the same Time, by the Surface of the Water A B, to be as the Series of odd Numbers, beginning at the greatest; which will be discovered more plainly in the Tables that will by-and-by be presented to View.

AGREEABLE to Experiments of this Kind, the same *Torricelli* proposed (though he never finished it) a Problem, to find a Vessel of such a Figure, that being pierced at the Bottom with a small Hole, the Water should go out, its upper Surfaces descending from equal Heights in equal Times. As suppose in the Conoidal Figure, *Fig. 1. Tab. seq.* BL is to BN as the squared Square of LM is to the squared Square of NO, and BN to BH as the squared Square of NO to the squared Square of HK, and so on; the Water will descend from A D C uniformly, till it comes to the Hole at B; for, let BP be the mean Proportional between BD and BH, since the Square squared of KH and of DC, are to each other as the Heights BH, BD; the Squares of HK, DC, will be in a subduplicate Ratio of BH to BD, or as the Heights BP, BD; but the Velocity (and consequently the Quantity of Water) that goes out at B, by Reason of the Pressure of BH, is in a subduplicate Ratio of BD, BH, that is to say, as BP to BD; therefore the Velocity of the Water descending from H is to the Velocity of the Water descending from D, as the Square of HK is to the Square of DC: But the circular Surface of the Water at H is to the circular Surface of the Water at D, as the Square HK to the Square of DC; therefore they will descend and run out one as fast as the other: And if the Surfaces A D C run out in a Second, the Surface G H K will run out in a Second likewise, since the Quantities are as the Velocities.

THE same Thing will happen to the other Surfaces at E and F, &c. but the Hole at B must be so regulated, that no considerable Acceleration

Acceleration may be made, and that the Water may not go out of the Hole irregularly, but in exact Proportion to its Weight. And, as *Marriotte* observes, that such a Vessel will or may serve for a Clepsydra or Water-Clock, an oblong Reservoir of that Shape may be of excellent Use in the Driving of Mill-Wheels where Water is scarce, and the Opening is at the Bottom of it.

BUT to return from this short Digression, to which I have been insensibly carry'd, it is plain, from the foregoing Experiments, that the Supply of Water, which comes from one Place to another, is according to the different Sizes of the Spouts or Pipes of Conduct from which it proceeds, and according to the different Heights of the Head-Spring or Reservoir from whence it falls; because it is by the Difference of the Velocity or Force of Water, proceeding from Heights greater or lesser, that the Quantity of Water proceeding therefrom is either greater or lesser; for the exact Calculation of all which, the World is obliged to that curious and most exact Calculator of Fluids Monsieur *Marriotte*, in his late excellent Treatise, translated by the Reverend Dr. *Desaguliers*: But (as has been before noted) the *French* Measures differing pretty much from ours in *England*, it will be proper to say from the foregoing Tables, that the *French* Pint (something near our Quart) is to our *English* Pint as 36 to 52; that the *Paris* Muid is to our *English* Hoghead as 504 to 654; that the cubick Foot *French* is to our cubick Foot as 16 to 15, or rather, as their Squares 4096 are to 3375: That their Ounce, and consequently their Pound, and other Weights, are to ours as 93 to 100. And, finally, that the Weight in Pounds of a cubical Foot *French*, is to the Weight in Pounds of a cubical Foot *English*, as 79 is to 65, or thereabouts. So that if a Column of Water of 12 Foot high, and half a Foot square *French*, weighs 210 *l.* the same Number of Water in *English* Feet (being smaller than the *French*) will weigh but 172 *l.* $\frac{7}{9}$.

THE next Chapter illustrates the Practice of what goes before.



C H A P. XXXI.

A farther Calculation of the Coming-in of Water from Engines, or otherwise.

WE are now come to the real Calculation of the Motion of Fluids or Water in Pipes, which by the Rules *Marriotte* and others have laid down, will (through a Bore of three Lines, commonly call'd an Inch of Water) give 14 Pints in a Minute, and consequently, 3 *Paris* Muids about 2 Hgds. $\frac{3}{4}$ *English* in an Hour, and 56 *English* Hogsheads in 24 Hours, provided the Distance and the Friction occasion'd thereby be not too great, and that the Top of the Reservoir lie something above the Hole or Spout, out of which the Water proceeds; horizontal Jets giving more than those that spout upwards, and less than those which spout downwards; as Reason and Experience demonstrate.

AGREEABLE to this Rule of 12 Foot or 13 Foot high, above the Hole of an Adjutage of 3 Lines will give an Inch of Water, that is 14 Pints *French*, about 20 $\frac{2}{9}$ Pints *English* in a Minute, as above, as it spouts upwards, and when the Reservoirs have the same Height, but different Adjutages, the Expence of the Water will be in the same Proportion as the Holes of the Adjutages, that is, as the Squares of the Diameters of the said Holes. Thus, if a Reservoir of 13 Foot has an Adjutage of 6 Lines, and the Pipe of Conduct be, as it ought, 4 Times the same, that is, 2 Inches, it will give 4 Inches of Water: And if it is a Hole of one Inch Bore, the Pipe of Conduct being 4 Times as much, it will give 16 Inches in spouting upwards, provided the Pipe of Conduct which brings down be of a sufficient Bore all the Way, according to these Rules.

IN order to calculate the Expence of Water, take the Square of 3, which is 9, and if the Adjutage has a Diameter of five Lines, you must work thus by the *Rule of Three*; saying, If 9, the Square of 3, gives 14 Pints *French* in a Minute, how much will 25, the Square of 5, give? and the Answer will be 38 $\frac{2}{3}$, being near 39; according to which the following Table is made.

A Table

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A Table of the Expence of Water in a Minute through Spouts of different Bores, the Reservoir 12 Foot high.

	Pints French.	Pints English.
Through an Adjutage of 1 Line Diameter	$1\frac{1}{2}$	$2\frac{1}{6}$
2 Lines	$6\frac{1}{8}$	$9\frac{1}{9}$
3 Lines	14	$20\frac{2}{9}$
4 Lines	25	$36\frac{1}{9}$
5 Lines	39	$56\frac{1}{6}$
6 Lines	56	$80\frac{8}{9}$
7 Lines	76	$109\frac{2}{4}$
8 Lines	110	$158\frac{5}{9}$
9 Lines	126	$184\frac{3}{4}$
10 Lines	155	$223\frac{8}{9}$
11 Lines	188	$271\frac{5}{9}$
12 Lines, or 1 Inch,	224	$323\frac{2}{9}$

To return to Practice, according to the afore-mentioned Table, if a Pipe of an Inch Bore give 224 Pints *French*, or rather 323 Pints *English* in a Minute, how much will a Pipe of 2 Inches Bore give? State the Question thus:

If 1, the Square of 1, give 323, what will 4, the Square of 2 give? Answer 1292 Pints *English*. See the Operation.

$$\begin{array}{r}
 1-323. \quad 4 \\
 \quad \quad 4 \\
 \hline
 \quad 1292 \\
 \hline
 \end{array}$$

WHEN the Heights of Water in Reservoirs are different, the highest give more than the others in a subduplicate Ratio of their Heights, that is, as the least Height is to the mean Proportional betwixt it and the greatest Height.

ACCORDING to this, if the Surface of the Water of the lowest Reservoir is 3 Foot high, and the Spout 3 Lines, you must take 6, which is the mean Proportional between 3 and 12; and because 6 is to 3 as 14 is to 7, it may therefore be concluded, that a Reservoir

Reservoir of 3 Foot high will give $\frac{1}{2}$ an Inch of Water, that is, 7 Pints *French*, or 10 Pints near $\frac{1}{4}$ *English*, through a Hole of 3 Lines; if the Height was of 4 Foot, you must take 48, the Product of 4 by 12, whose square Root is near 7; then say, as 12 is to 7, so is 14 to a Number unknown, which by the Operation appears to be $8\frac{1}{6}$; and shews that such a Jet will give 8 Pints $\frac{1}{6}$ *French*, about 11 Pints $\frac{1}{4}$ *English*, in a Minute; and on Calculations of this Kind the following Table depends.

	Foot	Pints French	Pints English
A Reservoir of	6	high gave 10	14 $\frac{1}{4}$ nearly
	8	11 $\frac{1}{2}$	15 $\frac{1}{3}$
	9	12 $\frac{1}{6}$	17 $\frac{1}{4}$
	10	12 $\frac{5}{8}$	17 $\frac{3}{4}$
	12	14	20 $\frac{2}{9}$
	15	15 $\frac{1}{3}$	21 $\frac{2}{9}$
	18	17 $\frac{1}{6}$	24 $\frac{2}{3}$
	20	18 $\frac{1}{2}$	26 $\frac{2}{9}$
	25	20 $\frac{1}{6}$	27 $\frac{4}{9}$
	30	22 $\frac{1}{6}$	32
	35	24 <i>fere</i>	34 $\frac{2}{3}$
	40	25 $\frac{2}{3}$	36 $\frac{1}{4}$
	45	27 $\frac{1}{6}$	39 $\frac{1}{4}$
	48	28, or 2 Inches	40 $\frac{4}{9}$

Now, to explain with the curious *Marriott*, and his learned Translator, what is meant by an Inch of Water, as in the last Line, where there is set down 28 Pints, or two Inches; it is sufficient to observe, that it is an Unit, or Term, that *Marriott* chooses to express himself by, as he has done before, when he says, that if a Spring gives 7 Pints *French*, onwards of 14 Pints *English*, in a Minute, it may be said to give an Inch of Water: If it afford 14 Pints *French* in half, or 20 Pints *English* in a Minute, it may be said to give two Inches, and so on.

BUT it must be noted, that when you make Tryal of any of the foregoing Experiments, whether they are designed to demonstrate *French* or *English* Measures, you must make the Hole 1 Inch

A a

and

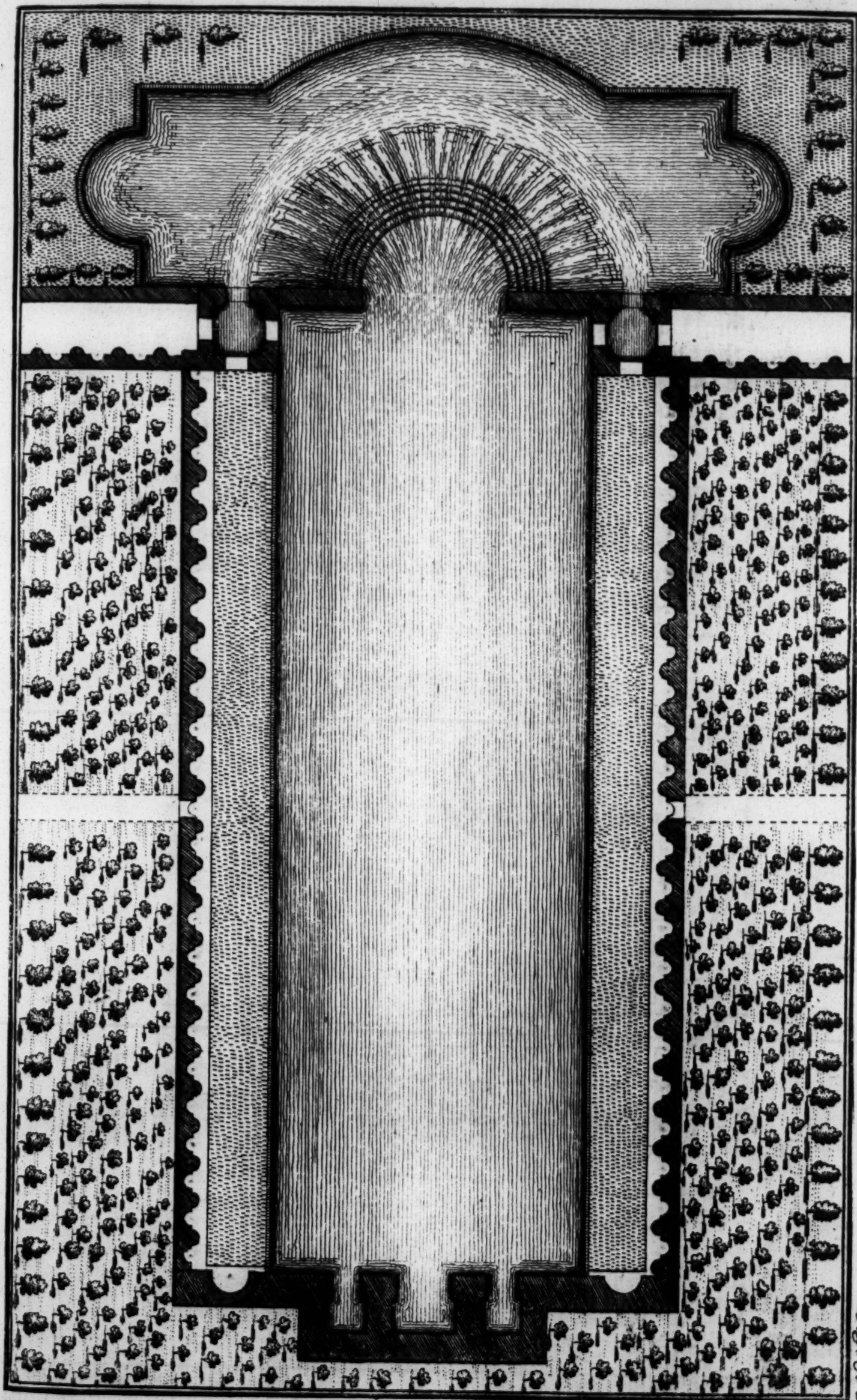
and 1 Line, or 1 Inch $\frac{1}{2}$ Diameter, very nearly, the *French* Inch being pretty near as 13 to 12 is to ours *English*.

IT having been proved then, by dividing 144 by 9, that a Bore of an Inch Diameter will (according to the Proportions before recited, being 16 Times as large as a Bore of 3 Lines, coming from a Reservoir 12 Foot high) produce 224 Pints *Paris* Measure, or about 324 of *English* Measure in a Minute; and that all other Heights in the foregoing Table must consequently follow the same Proportion, I have calculated the Table that follows, in which will be seen the Quantity of Water, *English* Measure, that any Reservoir will give, from 48 to 6 Foot high, according to the different Sizes of Piping, from 1 Inch to 8 Diameter: The first Column is the Height of the Reservoir, and the other seventeen the Diameters of the Pipes.

AND from this and what goes before it is plain, that most Calculations relating to the Coming-in and Going-out of Water, may be solved; only it must be observed in all Diameters or Bores of Pipes, they must be made according to the *French* Inch, which is to ours, as the Square of 16, which is 256, is to the Square of 15, which is 225: Say we then, as 225 is to 226, so is 144 to a fourth Number required, which is 174, the Square whereof is very near 13 Lines $\frac{1}{2}$, or 1 Inch $\frac{1}{2}$ $\frac{1}{2}$ Line: And so much must the Diameter of the Inch Pipe be, to answer the following Table; if a 2 Inch Pipe, it must be 2 Inches 3 Lines; if a 3 Inch Pipe, 3 Inches 4 Lines $\frac{1}{2}$, and so on.

N. B. In what is set down in the following Table, proper Allowance is made for Friction, or rather the Interposition of the Air; but as the Valves before mentioned are now much in Use, that Friction or Interposition of Air, call it which you will, will be in a great measure taken off; and these Clacks, or rather Valves, may be used in Leaden, Wooden, or Iron Pipes, as well as Clay; so that the following Table, if it does err, yet is an Error on the right Side, and the Quantity of Water here set down, with the respective Heights to which it has been said to rise, will certainly be enough.

A Table





A Table shewing what Quantity of Water, English Measure, any Reservoir will discharge, from 48 to 6 Foot high according to the different Sizes of Piping from 1 Inch to 8 Diameter, in a Minute.

Height of the Reserv	In.	Inch. 1 1/2	Inch. 2	Inch. 2 1/2	Inch. 3	Inch. 3 1/2	Inch. 4	Inch. 4 1/2	Inch. 5	Inch. 5 1/2	Inch. 6	Inch. 7	Inch. 8	Inch. 9	Inch. 10	Inch. 11	Inch. 12
6 0	240	280	960	1440	2160	2880	3840	4800	6000	7200	8640	11760	15360	19440	24000	29040	34960
8 0	245	490	980	1470	2205	2940	3870	5900	6025	7350	8820	12005	16780	19845	24500	29646	36380
9 0	276	556	1104	1656	2484	2912	4416	5520	6900	8280	9936	13524	17664	22356	27600	32396	39744
10 0	284	568	1136	1704	2556	3408	4544	5680	7100	8420	10224	13916	18176	22704	28400	34364	40896
12 0	324	648	1296	1944	2916	3888	5184	6480	8100	9720	11664	15776	20736	26244	32400	39204	46659
15 0	345	680	1380	2070	3105	4140	5520	6900	8125	10350	12420	16905	22080	27945	34500	41754	49680
18 0	396	796	1584	2376	3564	4652	6336	7920	8900	11880	14256	18404	25344	32076	39600	47916	55924
20 0	429	858	1716	2574	3861	5148	6741	8580	10725	12870	15444	21021	27456	34749	42900	51909	61776
25 0	439	878	1746	2634	3951	5268	7024	8780	10975	13170	15804	21511	28096	35549	43900	53119	63216
30 0	512	1024	2048	3072	4508	6144	8192	10240	12800	15360	18432	25088	32768	41472	51200	61952	73728
35 0	556	1112	2224	3336	4994	6672	8896	11120	13900	16680	20016	27234	35584	44936	55600	66308	80064
40 0	580	1160	2378	3480	5220	6960	9280	11600	14500	17400	20880	28420	36120	46980	58000	70180	83520
45 0	628	1256	2512	3768	5752	7536	10048	12560	15700	18840	22608	30772	40192	50864	62800	75978	90432
48 0	647	1294	2588	3862	5933	7764	10352	12940	16165	19410	23292	31703	41208	52407	64700	76287	93168

Note, The Numbers above recited are Pints English Measure; to reduce which into Hogheads, &c. you must divide by the Number of Pints in a Hoghead; all which will be found in the Tables which are calculated for that Purpose.

So that the Uses of the foregoing Table being very plain, I need not enlarge on it. If you would know how much Water a 4 Inch Pipe will yield in an Hour, that comes from a Reservoir 30 Foot high, look in the Table against 30, and under the 4, and you will find 8192 Pints in a Minute; that multiplied by 60, gives 491520, and divided by 512, the Pints in an Ale Hogshead, and the Answer is 970 Hogsheads.

AGAIN, in like Manner, if you would know how many Hogsheads in an Hour a Pipe of 2 Inches Bore, will produce from the same Height, there will be answering 2048, which, multiplied by 60, produces near 231 in an Hour; but if it was for a less Height, as suppose 6 Foot, it would give but 112 Hogsheads in an Hour; and all this, when the Reservoir is under 150 or 200 Yards, at most, of the Place; for if it be a long Length, and there be Turnings or Windings, and up-hill and down in it, it would cause a great Friction, and would not yield above 50 or 60 Hogsheads, at most, in an Hour, as Experience does sufficiently evince; for if the Allowance for Friction be as 9 to 4, as the learned Annotator on *Marriotte* says it is, then a Pipe of 2 Inches Diameter, and that goes above 1000 Yards; as suppose 12, 13, or 1400, then such a Pipe would give but 49 Hogsheads $\frac{7}{9}$.

AND thus much for the Coming-in and Going-out of Water in Pipes from Reservoirs of different Heights, where there is little or no Friction; but, 'tis much to be feared, that Water that is raised by Engines will not produce such great Quantities, nor scarce so much as Reservoirs at a great Distance, allowing for Friction; since 'tis plain, from the Principles of all those who have wrote of *Statics*, That a Force, which forces up a Body perpendicularly, grows less equally: Because the Gravity of the Body, which is thrown up constantly, pushes it downwards again; and so its Motion upwards must continually decrease, and be wholly destroy'd, when the Impetus upwards, which is receiv'd from that impulsive Power that throws it up, becomes equal to that Impetus which its own Gravity gives it downwards, that is, that Bodies thrown upwards must be retarded, and cease to rise, as soon as the two Impulses are become equal, and then immediately begin to descend again; because then the Impulse of Gravity is greater than that of the Projection; since Gravity lessens the Velocity of the Impulse upwards, and by its contrary Action destroys the Motion upwards, with the same Force that it would produce a Motion downwards, which is uniformly, according to the Laws of Motion accelerated, the Force which pushes upwards must also decrease uniformly.

formly. And since the Descent of Water coming from different Heights is found to increase, by the foregoing Tables and Accounts, in a subduplicate Ratio of its Height, its Rise, and also Quantity, must consequently decrease in the same Proportion.

THUS, to invert the Terms, if an Engine throw up 647 Pints of Water 6 Foot high, through a Pipe of an Inch Diameter, the same Engine will not be able to throw up above 240 Pints to a Height of 48 Foot, through a Pipe of like Diameter. But as the most exact Rules that can be given in Theory, will, in all Probability, fall short, and, perhaps, wide of the Truth, when reduced to Practice, I have with some Difficulty procured (from some of the most eminent Places in *England*, where Engines are made,) Account of the Bore of their Pipes, the Distance the Water is carry'd, and the Height to which it rises; because, farther than yet mentioned, the impulsive Force of an Engine (notwithstanding Engineers now put two, three, or four Regulators to it) is alternate, or in some other Degree intermissive; which is the Occasion that Engines will by no Means yield the same Quantity of Water, as Reservoirs or Springs (whose Motion is regular and uniform) will. And this Account will, in a great Measure, explain the Effect of every particular Kind of Engines, and how preferable they are, in many Circumstances, to one another.

C H A P. XXXII.

Of Friction, its Etymology, and the Effect it has on Pipes of Conduct, &c.

F*riçtio*, a Substantive of *Fricco*, has its Derivation, as some will have it, from the *Greek* of *Frigeo*, or rather (as *Schrevelius* notes it) of *frigo*, *torreo*, *torrefacio*, to heat, make warm, burn, and the like; from whence, says that laborious Author, comes *φρύγμις* & *torrefactio*, *frixio* vel *friçtio*; and *Coles* in his little Dictionary will have it from the *Greek* *τρίβω*, or from the *Hebrew* *Pur*, which translated into the *Latin* Language signifies *disrumpi*, i. e. to break, rub, chafe, or fret; in all which Senses it may well be taken, as it imports that Letting, Hindrance, or Stoppage in Fluids, and in all Mechanick and Hydraulick Motion, occasion'd by that Rubbing that is inseparable from the Laws of Motion in Engines, &c.

It is a Word that seems not so well understood, at least not heretofore used in the Sense it now is, as whoever will give himself the Trouble to inspect *Scapula*, and other ancient *Lexicons* and *Glossaries*, will find; tho' there we find, that *Celsus*, *Lib. 1.* makes use of it, in a Case not much unparallel to the Sense we now do, when speaking of a Journey he had taken, says, *in ipso quoque itinere frequens Frictio erat*: But the learned *Mersennius*, *Gallilæo*, and others have used it in a much larger Sense, in their Applications of it to Mechanical and Hydrostatical Calculations; and *Wallis* is found (tho' he has not defin'd the Word, as he has done many others in these Arts) in many Places of his Treatise on the Axis in *Peritrochio*, to use the Word with great Freedom, however limited the same was in antient Authors: Let me set it down in his own Words, *Cap. 7. Prop. 3. Quæ hinc oritur frictio, impedit quominus orbiculus, circa axem suum expedite volvatur*; and again, a little lower, *Et quidem eo magis, quo axis major est propter majorem, propterea frictionem*. And, to conclude, a little farther he says, *Et propterea ob frictionem sæpius repetendam difficilior movebitur roto minor*.

AND from these Intimations it appears to be, that the learned *Harris*, in his *Lexicon Technicum*, *Vol. I. sub titulo F.* says of it, that it is a Word often used by Writers on Mechanics, for the Resistance which arises to the Motion of any Engine from the Matter (and I may add the Shape and Size of the Wheels, &c.) rubbing against one another, and against any other Body; and of this Resistance, arising from Friction, he tells us, there was a large Discourse printed in the *Memoirs* of the *Royal Academy* of Sciences at *Paris* for the Year 1699, by *Monf. Amontou*, wherein that ingenious Author makes several Experiments, which give Rules for to find out and calculate Tables of this Resistance arising from Friction, and of that which is the Result of all that Rubbing, Chafing, and Stoppage of Cords used in Pulleys, the Substance of which shall be, if this Book can be procured, exhibited in its proper Place. Returning now to the Friction that is in Pipes, wherein it must be observed, that later Writers on Hydrostatics have used this Word in a more extensive Manner, than what is to be found in *Gallilæo*, *Wallis*, and others, who have treated of Motion; I mean the celebrated *Marriotte*, who by some curious Observations has found, that Water in Pipes is considerably stopp'd by the Friction that is against the Sides of them, occasion'd, as some will have it, by the Viscosity and Cohæsion of the Particles of Water one to another, which being, as it were hook'd together, impede and hinder each other in their Passage, especially in
great

great Lengths, of which whoever reads *Part V. Discourse 1.* concerning Pipes of Conduct in *Marriotte's* elaborate Treatise of Hydrostaticks, may be more particularly inform'd.

Now, as from hence it chiefly comes to pass, that Water that passes a great Way, and from a Spring-Head, as it were naturally, never rises well to its own Level, how much soever may (to the Disadvantage of young Hydrostaticians have been said to the contrary, it will not be improper, in the Course of this Chapter, to consider something of the Method for the Determination of this Friction, or the Resistance that is in the Passage of Water through long Tracts of Land, and in narrow Tubes, the Velocity of which is stopp'd by this Friction; for the Discovery of which, take the following Experiment, as we have it from *Marriotte* aforesaid.

LET *A B C D* (*Fig. 1. Tab. seq.*) be a Pipe of 6 Inches Diameter, and 6 Foot high; the Pipe *C E* is 3 Inches Diameter, and the Pipe *G F* 1 Inch: Three Holes were made at the Points *H I L*, that at *H* was 2 Lines wide, that at *I* 4 Lines, and the last at *L* was 8 Lines wide: In the other Branch *F G*, the Holes *K N M* were disposed after the same Manner, in respect of their Nearness to the Tube *A B C D*. The Pipe *A D* being full, the Operator let the Water spout successively through the three Holes *H I L*, the other still continuing shut; the Jet at *L* rose the highest, being the widest; but a narrow causes a considerable Friction that retards the Velocity of the Water, and hinders it from running fast enough to supply the Adjutage. But in the Holes *H* and *K*, as the Velocity thro' the Pipe is 16 Times less than when the Water goes through *L* and *M*, the Friction in the narrower Pipe is inconsiderable, and does not sensibly retard the Jet *K* more than the Jet *H*, and they both rise pretty near to the same Height. It follows likewise, that if you diminish the two Holes *I* and *N*, for Example, each of them a Line, then the Jet thorough *F* will not rise so high as it did, and that through *N* will rise higher; because there will be less Friction in the Pipe *F G*, that overcomes the Defect from the Air's Resistance; and in the Pipe *C E*, this Diminution of Friction will not be considerable, but the Resistance of the Air will be a little greater, than in that of 4 Lines; and this it is that has deceiv'd a great many Persons, that have made their Experiments in narrow Pipes, as *F G*, and they have, with the greatest Part of the Fountain-Makers, concluded, that Water rose higher through narrow Adjutages, than through wide ones, which is contrary to Reason and Experience, provided the Pipe of Conduct be not too narrow, that is, to supply them.

THE same Thing happens when the Adjutages are 6 or 7 Inches long, or even 2 or 3 Foot, the Jet will be higher through a plain Hole in a Plate, not above a Line, or a Line and a half thick, the Experiment will (according to *Marriotte*) be easily made: If you have a Pipe of 6 or 7 Inches Diameter, as *ABCD*, *Fig. 2.* and in the Pipe *EF* of a sufficient Bore, 2 equal Holes be made at *G* and *H*, the first having the Adjutage *GI*, and the other only the Thickness of the Metal; for you will see the Jet through *H* will go much higher than through *GI*; and the more you diminish the Height of *IG*, the nearer will its Jet rise to that of *H*; whence it follows, that the long Adjutages that are put to the Mouths of Dolphins in Fountains are very defective.

AND tho' the Adjutages should be a little conical, the Jet will still be retarded; concerning which take the following Experiment: A Glass Pipe, a Foot in Height, and an Inch Diameter, having a Hole of two Lines and a half, spouted only ten Inches and a half high, when there was a little Cone in it; but when it was made without a Cone, it spouted eleven Inches and a half; which ought to be a good Direction to those that make Adjutages or Spouts to Fountains, not to contract them at Top, as many do, but to make them exactly cylindrical; nor likewise to contract the Termination of the Pipes of Conduct all at once, but by Degrees, and in such a Manner, that the Friction may be as little as possible; since 'tis this, that by all the Experiments which have been made, that causes that Friction, which depresses, instead of forwarding, the Rising of the Jets, and Passage of Water in Pipes.

TO trace all the Experiments that are and may be made to demonstrate this Friction, would be a Work of itself, and entirely beyond the Room I can allow in this Treatise; because a Multitude of Examples would rather puzzle, than instruct any Learner in the Practice of Hydrostaticks and Hydraulicks, for which this Design is chiefly calculated; nor indeed can the Experiments that are made in small Cases have their full Weight in larger, it being found, (as has been already hinted in the Preface) that *Marriotte* does not allow enough for the Decrease of the Velocity of Water through a long Pipe of Conduct; all which having been so amply laid down in the Preface, I need not repeat it here again; but that this Friction is nearly in Proportion to the Length that it runs, rather than to the Friction that is against the Side of the Pipes; nor is it indeed an easy Matter to distinguish from which of the Causes it is, that this Velocity of Water is stopp'd, whether from Friction or the Cohæion of watery Particles one to another, or from the Resistance that is in Air, which possesses

possesses itself of all Vacuities, and, till it is expell'd by the greater Force of Water, must occasion a considerable Resistance thereto, as the Noise and Roaring of Water in Pipes do sufficiently demonstrate.

THERE is also another Reason, why it is not so easy to determine the *Rationale* of Friction by the before-mentioned Experiments, and which is, That a little Thread of Water finds more Resistance (especially in open Air) at its first coming out, than great Jets do; as small Bullets or Shot, tho' shot out of the same Piece, will not reach so far as large ones. And there is yet another, which proceeds from the different Impulse or Force of Water from Engines or Reservoirs of different Heights. All which Circumstances, I say, produce different Effects, as the Causes are different. But be this Decrease of the Velocity of Water from what Cause it will, the Table that will be by-and-by inserted, corroborated, and explain'd, as it will be from real Facts in larger Cases, will be as near the Truth as can be.

IT will be sufficient, in Addition to what has been said on this Head, to add, that the Resistance of Air, and the other Causes before-mentioned, is such, that Water (how duly and regularly soever plac'd, and how well soever adjusted the Pipes of Conduct and their Adjutages are) will not rise by about $\frac{1}{8}$ or $\frac{1}{9}$ in open Air, nor by a tenth in enclosed Pipes (where the Distances are great) so high as their original Reservoir or Basin.

Of the Proportion of Conduct-Pipes.

FROM those curious Observations that Monsieur *Marriotte* has made at *Chantilly*, and other Places, and from large Adjutages and Pipes of Conduct, it appears, and may be taken for a fundamental Rule, that a Reservoir of 52 Foot high ought to have a Conduct-Pipe of 3 Inches Diameter, when the Adjutage is 6 Lines, and that the Jet will then rise to the greatest Height that it ought to have.

TO compare the Breadth of this Conduct-Pipe with that which Reservoirs ought to have, and the Breadth of Adjutages, the following is a proper Rule, supposing that the Velocity of the running Water be equal in both Pipes, and that there be no more Friction in one than the other: But if the Number of Inches be quadruple, the Section of the Bore of the Conduct must be four Times greater that the Velocity of the Pipes may be equal.

HERE follows the Rule as it is established by Mr. *Marriotte*;
B b As

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As the Number of Inches which one Jet gives, is to the Number of Inches which another Jet gives; so is the Square of the Diameter of the Conduct-Pipe of the first, to the Square of the Diameter of the Conduct-Pipe of the other.

Example :

IF you would know what Diameter you must give your Conduct-Pipe to have a Jet 100 Foot, through an Adjutage of 12 Lines, you must take a Height of 52 Foot, as above, for your Standard, which through an Adjutage of 6 Lines, having the Pipe 3 Inches Diameter, gives 8 Inches; and that because, by the Table of the Heights of Jets, the Reservoir of a Jet of 100 Foot ought to be $133\frac{1}{3}$; you say then, As 52 is to 133, so 64, the Square of 8, is to 170; and the Square Root of 170 being pretty near 31, you see, that a Reservoir of 133 Foot, through 6 Lines, will give 13 Inches, and through an Adjutage of 12 Lines, 52 Inches of Water. Then, as 8 is to 52, so is 9, the Square of 3, (which the Diameter of the Pipe ought to be,) to 58, whose square Root is 7, and near $\frac{2}{3}$, which will be the Diameter of the Pipe that was sought; but, for greater Security, you may, says our oft-quoted Author, give it 8 Inches.

To sum up all that has been said, and to adjust the Friction we have been so long discoursing of in this Chapter, the general Rule is, that Water brought a considerable Distance, loses $\frac{1}{8}$ of its Velocity; or, in other Words, that it will not rise so high as the Spring-Head is by $\frac{1}{8}$; so that if the Descent from a Spring-Head to a Reservoir or Building be 128 Foot, you are, according to this general Rule, by which many Plumbers and others are governed, to divide it by 8, and the Produce will be 16, which shews that the Water will not rise so high as the Spring-Head by 16 Foot; and that, consequently, instead of the Water's rising to 128 Foot high, it will only rise to 112 Foot, 16 Foot being allow'd for Friction, or the Interposition of Air, &c.

'TIS true, where the Fall of Water is so great, as it is in the foregoing Example, there will be little Occasion to reason so minutely concerning the Friction that is to be allow'd: But where the Fall is not above 8 or 10 Foot, and at a great Distance, 'tis there that an exact Calculation is very necessary, lest the Owner be disappointed in his Labour and Expectation.

ACCORDING to some of the Rules before-mentioned, the natural Current or Fall for Water must be at least two Foot in a Mile;
and

and the Distance here being suppos'd to be 526 Yards running, the Question is, how many Inches will be requisite for such a Current or Dependance.

See the Operation.

IF 1760 require 24 Inches, what will 526 Yards require?

$$\begin{array}{r}
 24 \\
 \hline
 2104 \\
 1152 \\
 \hline
 1760 \quad 13624 \quad \text{Inches.} \quad (7 \frac{1}{17} \frac{2}{60}) \\
 1304 \\
 \hline
 \end{array}$$

AND the Answer is 7 Inches and near $\frac{2}{3}$. Then again, to determine the Friction, suppose that the natural Fall be 12 Foot in this Length of 526 Yards, divide the 12 by 8, and the Produce is 1 Foot 6 Inches, which, added to the 2 Foot natural Fall, makes 2 Foot 1 Inch and $\frac{2}{3}$; so that 12 Foot is much more than sufficient, and, if you will, you may carry your Spring, and consequently your Reservoir, higher: And, in the first Case, were the Fall no more than 3, 4, or 5 Foot, such Water would pass.

BUT as this Allowance of $\frac{1}{8}$ of the Height of the Spring-Head is in general Terms, and according to the Rules the Plumbers have establish'd amongst themselves, is suppos'd to be sufficient and exact, yet by the curious Experiments of *Marriotte* and others, a more certain Rule for Friction may be establish'd.

THAT ingenious Author produces it as a certain Rule, That the Difference of the Heights of Jets, or he might have said, in other Words, the Descent of Water from the Original or Spring-Head to the Reservoir, or Place assign'd for its Use, is in a *subduplicate Ratio of its Height*: And tho' it is certain, that this Gentleman has made use of it, to demonstrate the Rise of Jets of Water in open Air, which has doubtless as great, or, perhaps, a much greater Effect, than any Friction in inclosed Pipes; yet by this it is, that we may come as near the Matter of Fact as possible, and be more certain as to our Calculations on this Head.

TO come then to Example, (*vid. Pag. 270. of Dr. Desaguiliers's Translation*), and which he seems to establish as a general Rule, up to or nearly equal to the Height of the Spring-Head, he allows, that a Reservoir (which, by the By, ought to be at least 10 or 15 Foot square) that is 5 Foot 1 Inch high, will raise the Water 5
B b 2
Foot,

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Foot, and so on, in a subduplicate Ratio to their respective Heights; and consequently, that, as to this, it is but one Inch abated of what it would rise to by Nature; and pursuant to this it is, that the following Table is calculated, which is from Rules which farther shew, that if a Spring of 5 Foot 1 Inch in Height abates only 1 Inch, the same Spring, being 10 Foot 4 Inches, will abate 4 Inches; and the higher you go, the greater will the Disproportion be.

The T A B L E.

The Height of the Spring-Head.		The Height the Water will rise to.	
Foot.	Inches.	Foot.	
5	1	5	0
10	4	10	0
15	9	15	0
21	4	20	0
27	1	25	0
33	0	30	0
39	1	35	0
45	4	40	0
51	9	45	0
58	4	50	0
65	1	55	0
72	0	60	0
79	1	65	0
86	4	70	0
93	9	75	0
101	4	80	0
109	1	85	0
117	0	90	0
125	1	95	0
133	4	100	0

AND this is, I think, sufficient as to the Friction allow'd for the Descent of Water in close Pipes, and a Demonstration, that an Allowance of $\frac{1}{8}$ can be no certain Rule for it. What remains to be observed on this Head will naturally fall in, when we come to treat of *Fets d'Eau*.

C H A P.

C H A P. XXXIII.

Of the several Rules in Arithmetick with which a Learner in Hydrostaticks ought to be informed.

IT is of great Import, in order to the better understanding and calculating of Water-Works, that the Learner make himself Master and be well acquainted with the several Rules of Arithmetick following.

I shall pass by *Numeration, Addition*, and the like, because it is supposed that few are unacquainted with those Rules; tho' there are others, such as the *Rule of Three*, the *Rule of False*, *Square Root*, &c. very necessary to be known by all Hydrostaticians, which they may be at a Loss to comprehend, tho' well skilled in many other Arts and Sciences, it being for the sake of such, that this Treatise is chiefly designed.

THE *Rule of Three* is the most useful of any that belongs to *Hydrostaticks*, it being from two Numbers known that a Third which is unknown is discovered, which we shall many Times have Occasion to mention, in the Course of this Treatise.

SUPPOSE then, according to a general Rule, laid down in the Expence or Coming-in of Water, that a Pipe or Spout of three Lines Bore give 14 Pints *French* of Water in a Minute, what will a Pipe or Spout of 7 Lines give?

See...

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See the Example :

SAY, as 9, the Square of 3, is to 14, so is 49, the Square of 7, to a 4th Number unknown.

$$\begin{array}{r}
 9 \quad 14 \quad 49 \\
 \quad \quad 14 \\
 \quad \quad \hline
 \quad \quad 196 \\
 \quad \quad 49 \\
 \quad \quad \hline
 9) \quad 686 \quad (76 \frac{2}{9} \\
 \quad \quad 63 \\
 \quad \quad \hline
 \quad \quad 56 \\
 \quad \quad 54 \\
 \quad \quad \hline
 \quad \quad 2 \\
 \quad \quad \hline
 \end{array}$$

And the Answer is 76 Pints $\frac{2}{9}$ of a Pint.

Of the Rule of False.

THE *Rule of False* is another Rule that is of some Use in Hydrostatical Calculations.

THERE is a Cistern with three unequal Cocks, containing 60 Gallons of Water; and if the greatest Cock be emptied in an Hour, if the second be opened, it will be emptied in three Hours, &c. Now it is demanded, in what Time the Cistern will be emptied, if all the Cocks run together.

NOW, as the Solution of all Questions in the *Rule of False* are perform'd from a supposed fictitious Number, to find out a real one, let the Calculator suppose, that the Cistern will empty itself in half an Hour's Time, or 30 Minutes; then there must empty at the greatest Cock 30 Gallons, or one half; at the second Cock 15 Gallons, or one Quarter; and at the least 10 Gallons, or one Sixth; which added together makes 55: But this is too little by 5.

SAY then, by the *Rule of Three*, if 55 Gallons be expended in 30 Minutes, what Time will 60 Gallons take to run out, or be expended in?

See

See the Example:

As 55 is to 30, so is 60 to a 4th Number sought for.

$$\begin{array}{r}
 30 \\
 \hline
 55) 1800 \quad (32 \frac{40}{55} \\
 \underline{165} \\
 150 \\
 \underline{110} \\
 40
 \end{array}$$

So that the Answer is 32 Minutes, and something more than 40 Seconds.

I SHALL only set down one Example more, from the *Double Rule of False*, with which I shall conclude what I have to observe on these two Rules, and the *Rule of Three*, from which all these Examples are deduced.

A Vessel holds 60 Gallons, and has 4 Cocks to it; and being fill'd with Water, or any other Liquor, if they be all set open at once, the Liquor will run out in 24 Hours Time: Now the 2d Cock will empty as much as the first, during the same Time; and the 3d will empty three Times as much as the 1st in the same Time; and the 4th will empty five Times as much as the first: The Question is, what Number of Gallons each Cock will empty?

The first Thing to be done is to add all the four Numbers together, thus:

1st Cock	1	Quantity.
2d Cock	1	equal.
3d Cock	4	Times as much.
4th Cock	5	Times as much.
In all	11	

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SAY then, if 11, the Quantities of Water in the Whole, require 60 Gallons, what will 1 require?

$$\begin{array}{r} 11 \quad 60 \quad 1 \\ \hline 1 \end{array}$$

$$\begin{array}{r} 11) 60 \quad (5 \frac{1}{11} \text{ the Quantity the first Cock empties, which} \\ \underline{55} \hspace{10em} \text{Quantity also the second Cock empties.} \\ 5 \\ \hline \end{array}$$

Again; If 11 requires 60, what will 4 require?

$$\begin{array}{r} 4 \\ \hline 11) 240 \quad (21 \frac{2}{11} \text{ the Quantity the 3d Cock must empty.} \\ \underline{22} \\ 20 \\ \underline{11} \\ 9 \end{array}$$

But the Integer being once found, the whole Sum may be easier found out in the following Manner; the first Quantity being $5 \frac{1}{11}$, the Case will stand thus;

	Gallons.
1st Cock will empty	$5 \frac{1}{11}$
2d Cock the same	$5 \frac{1}{11}$
3d Cock 4 Times the Quantity	$21 \frac{2}{11}$
4th Cock 5 Times as much	$27 \frac{3}{11}$

The Fractions added together make 22, }
 which is 2 Times the Denominator 11, } $\frac{60}{11}$ the Answer
 and so the Addition will stand thus: } required.

N. B. THE Questions before-going will be of considerable Use, when we come to treat particularly of the Coming-in of Water, and the Expencc or Going-out of the same; and altho' the same might be done quicker by the Rules of Algebra, yet as that is a Science understood by few, I have chosen to use this plain Method of Arithmetick.

Of

Of the Square Root, and its Uses in Hydrostaticks.

THE Square Root is likewise a Rule that ought to be well understood by Hydrostaticians.

Here follows a Table of the Simple Roots, with their Squares.

Roots.	1	2	3	4	5	6	7	8	9
Squares.	1	4	9	16	25	36	49	64	81

FOR Example, let 576 be a square Number required, of which you are to find the Root: You must begin on the right Hand, and make a Point at every second Figure, and then it will stand thus:

576, the Point being made over the 7.

THE first Thing I do is to find the nearest Square to 5, which by the Table is 4.

Subtract then $\frac{4}{176}$ from 576,
And there remains 176 and the Quotient is 24.

LOOK again into the Table, and find the nearest Square to the Root 17, and you will find it to be 4, which I place in the Quotient, which makes 24, and 16 remains.

AFTER this, you are to examine if the last 4 multiply'd by itself, will make out the Number 16 which remains, which you will find it will exactly do; and 576 proves to be an exact square Number, of which 24 is the Root.

AGAIN, suppose you were to find out the Square Root of any other Number, let it be of 119025.

You must first make Points either above or below every other Figure, beginning on the left Hand thus, 119025; or which is better, divide them into three Classes, and then the Figures stand thus: 11 | 90 | 25

$$\begin{array}{r|l|l} 2 & 90 & 25 \text{ (3} \\ 11 & & \\ 9 & & \end{array}$$

C c

THE

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THE 2d Operation then is to find the nearest Square of 11, which is 9, and that 9 deducted, the Sum stand thus: $\frac{9}{290 \overline{) 25}}$ for the two next Divisions.

THE third Operation is in this Form:

$$\begin{array}{r|l} 2 & 3 \\ 11 & 54 \\ 9 & 90 \\ & 64 \end{array} \begin{array}{l} 25 - (34 \\ 8 \end{array} \quad \left| \quad \begin{array}{r} 11 \ 90 \ 35 \ (34 \\ 9 \\ \hline 6) \ 290 \end{array}$$

IN the fourth Operation, the whole Quotient 34, being doubled, makes 68, and will be a new Divisor, to be put under the left Hand Figure 2, after this Manner: $119025 \ (34$

$$\begin{array}{r|l} 2 & 3 \\ 11 & 54 \\ 9 & 90 \\ & 64 \end{array} \begin{array}{l} 25 - (34 \\ 8 \end{array} \quad \left| \quad \begin{array}{r} 64) \ 290 \\ 256 \\ \hline 34 \end{array}$$

THE left Hand Figure 6 of this Divisor, since it can be had in 34 five Times, this new Quotient 5 is joined to the former behind the crooked, and is also set down under 5 in the vacant Place of the Classis; so that the Operation stands thus:

$$\begin{array}{r|l} 2 & 3 \\ 11 & 54 \\ 9 & 90 \\ & 64 \\ & 6 \end{array} \begin{array}{l} 25 \\ 85 \end{array} \ (345 \quad \left| \quad \begin{array}{r} 11 \ 90 \ 35 \ (345 \\ 9 \\ \hline 64) \ 290 \\ 256 \\ \hline 685) \ 03425 \\ 3425 \\ \hline \end{array}$$

C H A P. XXXIV.

Of several Weights and Measures necessary to be known for the better explaining the Division, Distribution, and Expence of Water.

FOR the better Calculation of the Quantity of Water coming from Engines and Springs, and the Expence thereof, in Fountains, Cascades, and the like, it will be necessary to set down the following Account with the Addition of such Tables of Weights and Measures, as are statutable and customary in *England*, and which most necessarily belong to this practical Treatise; which, when compar'd with those of *France*, the Learner may, with the more Certainty, compare and adjust those which *Marriotte* and others have made Use of in their Hydrostatical Calculations.

THAT ingenious Gentleman and his Reverend Translator tell us, that with them in *France* a cubick Foot of Water weighs 70 Pounds *French*, (i. e. $65\frac{1}{2}$ *English*) and contains 35 Pints *Paris* Measure; but by this it is plain, neither their Weights nor Measures are the same with ours; for it has been proved, by undoubted Experiments, that a cubick Foot of Water *English* weighs 76 Pounds *Troy* Weight, but of *Averdupois* but 62 *lib.* $\frac{1}{1000}$: And in this Account they tell us, that 70 *lib.* contains 36 Pints *Paris* Measure, when filled up to the Brim, (which must be near equal to so many Quarts *English*;) but if the Water (say they) rises above the Brims of the Vessel before it runs over, the *French* Pint (about our *English* Quart) will weigh (as before) 2 Pounds, and 35 such Pints only, will be contained in a cubick Foot. Now here, in like Manner, it is apparent, that they differ from us; for if half a Pint *French* weighs 1 Pound, as their Authors intimate, if it be compar'd with our *Troy* Weight, it is too little, if with our *Averdupois*, too much. It being found from the same careful Experiments, as before mentioned, that a cubick Foot of Water *Averdupois* is 62 *lib.* 9 *oz.* $\frac{4}{1000}$, or 76 Pound *Troy*: But I shall chuse to make use of *Averdupois* Weight in all my Calculations, rather than *Troy*; for tho' most Liquids that are sold are weigh'd by *Troy* Weight, yet as the *Averdupois* is the most general Weight now made use of, and as its

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Tables are the most agreeable to my present Purpose, when I say Pounds, or any other Number or Quantity of Weight, I mean that of *Averdupois*; and when I make use of any Quantity of liquid Measures, I mean that of Ale.

BUT if any one is so curious as to have his Account in *Troy* Weight, it is proper he should know from the ingenious and very careful Experiments of Dr. *Wybeard* and others, that 14 Pound *Averdupois* is equal to 17 *Troy*: To reduce the one to the other, say then, by the *Rule of Three*,

IF 14 Pound *Averdupois* be equal to 17 Pound *Troy*, how equal is 125 Pound to any Number unknown? Answer $151 \frac{1}{4}$.

See the Example.

$$\begin{array}{r}
 14 : 17 :: 125 \\
 \quad \quad 17 \\
 \quad \quad \hline
 \quad \quad 875 \\
 \quad \quad 125 \\
 14) 2125 \quad (151 \frac{1}{4} \\
 \quad \quad 72 \\
 \quad \quad \hline
 \quad \quad 25 \\
 \quad \quad \hline
 \quad \quad 11 \\
 \quad \quad \hline
 \end{array}$$

By which it appears that 125 *l. Averdupois* is equal to 151 *lib. Troy*.

To proceed with the ingenious *Marriotte* and his Translator, we are by them inform'd, that a *Paris* Muid or Barrel contains 280 *French*, (about 280 Quarts of *England*) or 288, if the Water is fill'd up to the Brim, (which it ought to be.) Now this likewise seems disagreeable to our *English* Measures; nor is our *English* Hogshead (as will appear by and by) equal to the Muid, which I beg Leave to explain, because of the Difficulty and Uncertainty that may be in the Way, when we come to calculate and compare *Fets d'Eau*, and the Expence of Water from Engines, or otherwise, I mean those of *England* with those of *France*.

To reconcile those two Measures together with the more Exactness, it is to be noted from Sir *Jonas Moore*, and others of good Note, in their Comparisons of Foreign Measures with the *English*, that the *French* Ounce is to ours (and which shall be the Standard from

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from whence we make all our Calculations and Tables,) as 93 is to 100, by which it will in its proper Place appear, that the *Paris* Muid is not equal to our *English* Hogshead.

Now to find the true Proportion between *French* and *English* Measures, if 14 Pints *French* (28 *English*) contains 26 Pounds, and in 14 Pints *English* there are contain'd 17 *lib.* $\frac{1}{2}$ *Averdupois*, and something more, (which it appears to do,) then the Difference between those two Measures, by doubling the 17, and 26 in order to avoid Fractions, is as about 36 to 52.

IF therefore a circular Hole of Water of an Inch Diameter give 14 *French* Pints in a Minute, how many *English* Pints will it give in the same Time; and because it will give more *English* than *French*, state it thus:

$$\begin{array}{r}
 36 : 52 :: 28 \\
 \hline
 52 \\
 \hline
 56 \\
 \hline
 140 \\
 \hline
 36) 1456 \quad \text{Answer.} \quad (40 \frac{16}{36} \text{ near } \frac{1}{2}. \\
 \hline
 16 \\
 \hline
 \end{array}$$

AND so many Pints *English* will a circular Hole of an Inch Diameter give, at the same Time that it gives 28 Pints *French*, (or about 28 Quarts *English*) Let 36 : 52 be then the Proportion.

AGAIN, if a Pint *French* of Water (about a Quart *English*) weighs 1 *lib.* $\frac{1}{4}$ *English*, then 288 Pints of the same Measure will make 504 Pounds *English*, and so many Pounds *English* a *Paris* Muid holds, and consequently the Proportion between the *English* Ale Hogshead and the *Paris* Muid is as 654 to 504, 654 Pounds *English* being the Contents of *English* Pounds in a Hogshead, as 504 *English* Pounds are in a *French* Muid: If therefore an Inch of Water, or in other Words, a circular Hole of an Inch Diameter, give 72 *Paris* Muids or Barrels in 24 Hours, how many *English* Hogsheads will it give? Answer, 55 Hogsheads, and about 30 Gallons.

LET

LET the Case be thus stated.

$$\begin{array}{r}
 654 : 504 :: 72 \\
 \hline
 1008 \\
 3528 \\
 \hline
 654 \overline{) 36288} \quad \text{Hogsh.} \\
 \underline{3588} \\
 318
 \end{array}
 \quad \left(55 \frac{3}{4} \text{ about } 30 \text{ Gallons.} \right)$$

IN like Manner may we (with the Observations made by *Wallis* and others) find out the Proportion that our *English* cubick Foot has to the *French*. The same learned Author, in *Prop. XI. Cap. 14. Pag. 728.* of his *Mechanical Essay*, saying, that upon a careful Examination, he had found the *Paris* Foot to exceed ours, as $14\frac{1}{2}$ is to $13\frac{1}{2}$ (or rather as 29 to 27, the Mercury in the Barometer rising but 27 Inches *French* to 29 *English*;) he might as well have said, as 14 is to 13, or 15 to 14; or as the ingenious Translator of *Marriotte* has it, as 16 is to 15; so that the cubical Content of the *French* Foot is to that of *England* as 4096 is to 3375; which is also what *Monfieur Marriotte*, in his practical Rules for *Jets d'Eau*, pag. 263. sets down, where he tells us, that a cubick Foot *Paris* Measure of Water weighs 70 Pound *French* or $65\frac{1}{4}$ *English*, then in a Foot solid *English* there are 62 lib. 9 oz. so that the Proportion between the *French* Foot and the *English* is near as 62 to 65, or nearer, as the Square of 15, which is 3375, (not 3528, as is by Mistake in *Marriotte*) is to 4096, the Square of 16.

To come to Example :

IN

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IN 256 cubick Feet *French*, how many cubick Feet *English*?

SAY, as ^{French.} 3375 is to ^{English.} 4096, so is 256 to the Content requir'd.

$$\begin{array}{r}
 24576 \\
 20480 \\
 8192 \\
 \hline
 3375 \) \ 1048576 \ (310 \frac{2126}{3375} \\
 \underline{3607} \\
 2326
 \end{array}$$

HAVING thus adjusted the Method of comparing of some of the *French* and *English* Measures together, it will be necessary to take a View of those that are purely *English*, and from thence draw out such Tables, as may complete the rest, so as to be of Use to the present Purpose, with their respective Weights, cubical Contents, &c. Nor let it be thought that these are needless Speculations, since it will be demonstrable enough in the Course of this Treatise, that the Weights and cubical Contents of all Fluids in all its various Circumstances, especially Water, is one of the most useful Parts of Knowledge, that belongs to practical Hydrostatics, and without which indeed all the Theory of it would be useles and insignificant.

THIS being premised, it will be requisite, in the next Place, to proceed to the Work itself, I mean that of *English* Weights and Measures.

ALL Measures of Capacity, (says the ingenious Mr. *Ward*, in his excellent Treatise of Arithmetick,) both liquid and dry, were at first made from *Troy* Weight, (*Vid.* the Statute of 9 *Hen.* III. 51 *Hen.* III. and 12 *Hen.* VII. &c.) where it was enacted, that eight Pounds *Troy* Weight of Wheat, gather'd out of the Middle of the Ear, should make one Gallon, and that there should be but one Measure for Wine, Ale, and Corn throughout this Realm, (as *Vid.* the Statute of 17 *Edw.* III. and 15 *Ric.* II.) but Time and Custom, says this ingenious Author, has alter'd Measures as well as Weights, and perhaps for the same Reason; there being now three different Measures, one for Wine, one for Ale and Beer, and another for Corn.

THE.

THE common Wine Gallon, by which Wine and Brandy, and other Liquors, are measur'd and sold, are suppos'd to contain 231 Cubick Inches, and should hold of pure Rain, or running Water eight Pound one Ounce and eleven Drams, as the very ingenious and curious Sir *Jonas Moore*, and others, have observ'd, and that is in *Averdupois* Weight, and nine Pound one Ounce one Dram in *Troy* Weight; therefore to get a true Wine-Gallon, make a square Vessel, that shall have all the Squares and Depths six Inches thirteen hundred Parts of an Inch; or if you weigh with *Averdupois* Weight, eight Pound one Ounce eleven Drams of pure running or Rain Water: Either of these, says this great Observer of Measures, will find out a true Gallon Wine-Measure.

But Dr. *Wybeard*, in his Treatise of Tectometry, Page 289. does suppose the Wine-Gallon to contain but 224 Inches, or 225 at most; and, pursuant to this, Mr. *Ward* tells us, that two very eminent Surveyors in the *Excise* made a very careful Experiment in a particular Vessel made for that Purpose before Mr. *Flamstead* and Mr. *Halley*, which confirm'd what Dr. *Wybeard* had set down before.

In and about *London* there are Distinctions of Beer and Ale, though not very widely different from each other; but in all other Parts of *England* the following Tables of Beer or Ale, whether strong or small, are to be observ'd, by a Statute of Excise made *Anno* 1689. with this Difference, that the Firkin of Beer contains nine Gallons, and consequently the Kilderkin eighteen Gallons; the Barrel thirty six, and the Hogshead seventy two; but in the Measure which I have chose rather to make use of, to wit, Ale, the Firkin is but eight Gallons, the Kilderkin sixteen, the Barrel thirty two, and the common Hogshead sixty four Gallons.

THE Gallon for Ale and Beer holds two hundred and eighty two Inches solid, and weighs of pure Water ten Pounds, three Ounces, $\frac{426}{1000}$, about seven Drams; therefore a square Vessel made to prove the Truth of this Gallon ought to be six Inches, and $\frac{66}{100}$ Parts of an Inch each Way, and the Weight ten Pound, three Ounces, forty Parts, *Averdupois*, as before.

Here

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HERE follows a Table of such Measures, with the Weights and Cubical Contents of each Vessel, as near as it is possible such Calculations should be made, being Averdupois Weight.

The TABLE.

Cub. Inch.	lb	3	3		Pint.		Gall.		Firk.		Kild.		Bar.	Hogf.
35 $\frac{1}{4}$	I	4	7	I										
282	IO	3	8	8	I									
2256	8I	12	O	64	32	I	O							
4512	163	4	O	128	64	16	2	I						
9024	327	O	O	256	128	32	4	2	I					
18048	654	O	O	512	256	64	8	4	2	I				

THE Use of this Table is so obvious, that I need not enlarge upon it, but shall only observe, that 18048 Cubick Inches are contain'd in one Hoghead, and that the same weighs 454 Pound. Now the Cubick Inches being reduc'd into Feet, produce something more than $10\frac{1}{2}$ Cubick Feet; and the 454 Pound reduc'd into hundred Weights, produce four hundred and six Pound, and so many hundred Weight are in a Hoghead *English*.

BEFORE I quit this Chapter, it is proper to set down from the curious Experiments of Dr. *Wybeard*, and others, that one Ounce of pure Running or Rain Water Troy will fill 1.8949 Inch, and one Ounce Averdupois 1.72556 Inch; one Pound Troy will fill 22.7368 solid Inches, and one Pound Averdupois, 27.609 solid Inches. One Foot solid will hold 76 Pound Troy, and sixty two Pound 500, as before, Averdupois.

HERE follows a Table for the converting solid Inches into Weight of Water Averdupois. The Table N^o I. turns solid Inches of Water into Ounces Averdupois, and the Table N^o II. turns Ounces Averdupois of Water into solid Inches, and are the Calculations of that excellent Mathematician Sir *Jonas Moore* before mentioned.

N^o I.

Ounces Aver.	
1	0. 59522
2	1. 159044
3	1. 738566
4	2. 313088
5	2. 897611
6	3. 477133
7	4. 056655
8	4. 636177
9	5. 215699

N^o II.

Inches and Parts.	
1	1. 72555
2	3. 45112
3	5. 17668
4	6. 90224
5	8. 62780
6	10. 35356
7	12. 07892
8	13. 80448
9	15. 53004

EXAMPLE: In an Ale-Gallon, 282 solid Inches, how many Ounces Averdupois.

ANSWER, 163.426 Ounces, or 16 Pound, 3.426 Ounces.

By the Table N^o I.

200--	115.904406
80--	46.361776
2--	1.159044

In all	163.426
--------	---------

So in 500 Ounces of Water there is 862 solid Inches by Table N^o II. and in a Foot solid, there will be answering 1728 Inches, 62 Pound, 9.414 Ounces.

THE nearest Proportion in Troy Weight, that 36 solid Inches will hold, is 19 Ounces Troy of Water, and one Pound Troy of Water will fill, as before recited, 22.7368 Inches, and one Pound Averdupois 27.609 Inches.

HENCE is found a very good Way to measure any irregular Body, that by no mechanical Art can otherwise be done: Fill any Vessel brim full of Water, and then dipping in your Body, receive carefully all the Water that runs over, and weigh it, and by the last two Tables, turn that Weight into solid Inches; otherwise, if your Vessel be regular that holds the Water, observing the Rising of the Water, and find the solid Feet or Inches answering.

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BUT more to our present Purpose, in Hydrostaticks, or rather Hydraulicks, let it be required to know the Cylindrical Weight of Water that an Engine must drive, the Length of whose Pipe is 1500 Yards, and the Pipe itself four Inches Diameter.

To find the Content of this Pipe at the End, say as 14 is to 11, so is 16, the Square of four, to the Content requir'd.

E X A M P L E.

$$\begin{array}{r}
 14 : 11 :: 16 \\
 \hline
 11 \\
 \hline
 16 \\
 16 \\
 \hline
 14 \overline{) 176} \text{ Inch.} \\
 \underline{36} \\
 8
 \end{array}$$

And the Answer is twelve Inches, and a little more than half a one, and so much is in an Inch in Length; but as there are 36 Inches long in a Yard, I multiply that by 12 and a half in the following Manner,

$$\begin{array}{r}
 36 \\
 12 \frac{1}{2} \\
 \hline
 432 \\
 18 \\
 \hline
 450
 \end{array}$$

And the Answer is 450 Inches in a Yard. Now by the Table;

Inch.	Ounces.
400--	231.3088
50--	28.9761
	260.6849

In all 260 Ounces, 6849, or 16 Pound 6 $\frac{1}{10}$ Ounces, or thereabouts; but that we reject as unnecessary. Dd d 2 SAY.

SAY we then, If one Yard Cylindrical of Water, in a Pipe of four Inches Diameter, weighs 16 Pound 4 Ounces, how much will 1500 Yards weigh? Answer, 24375 Pound, or 217 C. 71 lb. Weight, besides the Friction, Resistance, &c.

BUT because the calculating the Cubick and Cylindrical Weight of Water for Square Spouts, and circular Jets or Pipes, may be difficult and tedious to the Learner; I have, (to finish this Chapter) subjoin'd a Table of such Measures: And as it has been before observ'd, that the *French* Ounce (consequently all other of their Weights) are to the *English*, as 93 is to 100, so also it is observable, that as to Measures, the Cubick Foot *French* is to the *English* as the Square of 16, which is 4096, is to the Square of 15, which is 3375; and that consequently they are, in Respect to each other, as 79 to 65. Those who are skill'd in Algebra would do it quicker; but to demonstrate this the better and plainer,

LET it in the first Place be requir'd to know, That if a Foot Cubick of Water *French* weigh 69 Pound 12 Ounces, (as by *Ozanam's* Tables it appears to do,) how many Pound *English* does it weigh, suppose the *English* Foot were of equal Dimension with the *French*? Answer 79 Pound, &c.

E X A M P L E.

$$\begin{array}{r}
 93 : 100 :: 69 : 12 \\
 \hline
 474 \\
 69 \\
 12 \\
 \hline
 1176 \\
 100 \\
 \hline
 93 \overline{) 117600} \quad \begin{array}{r} 16 \\ 1264 \end{array} (79 \\
 \underline{246} \quad \underline{144} \\
 600 \quad 0 \\
 \underline{420} \\
 58
 \end{array}$$

Rejecting the Fraction, the Answer is 79 Pound. But as the *English* Foot is less than the *French*, and consequently contains a lesser

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leffer Number of Pounds in Proportion thereto, even as 4096 is to 3375, say we again,

As 4096 is to 3375, so is 79 to a fourth Number.

See the Operation:

$$\begin{array}{r}
 4096 : 3375 :: 79 \\
 \hline
 30384 \\
 23632 \\
 \hline
 4096 \overline{) 266724} (65 \quad \frac{464}{4096} \\
 \underline{20944} \\
 464
 \end{array}$$

By which it appears, that the Weight in Pounds of a Cubical Foot *French*, is to the Weight in Pounds of a Cubical Foot *English*, as 79 is to 65, or thereabouts; and the same holds good in Cylindrical Measure.

To come to Example then: Suppose, with *Marriotte, Disc. III. Rule v. Page 135.* of the Translation, that a Column of Water of twelve Foot high, and half a Foot Square *French*, weighs 210 Pounds *French*, how many Pounds *English* will twelve Foot of the same Water weigh? Now since the *English* contains a less Number of Inches than the *French* does, say,

As 79 is to 65, so is 210 to a fourth Number unknown.

$$\begin{array}{r}
 65 \\
 \hline
 1050 \\
 1260 \\
 \hline
 \text{Answer.} \\
 79 \overline{) 13650} (172 \quad \frac{72}{79} \\
 \underline{575} \\
 72
 \end{array}$$

AND pursuant to this Proportion, here follows two Tables of the Cubical and Cylindrical Weight of Water, from one Inch to a Foot

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Foot square or circular, taken at every Yard in Length, from which may at one View be seen what the cubical Contents, Weight, and Quantity of Water is, that drives all sorts of Mill-Wheel; and also what the Cylindrical Weight of Water is that a Mill-Wheel must drive at any determinate Length or Number of Yards.

A Table of the Cubical Contents and Weight of any square Jet, Spout, or Pipe, English Measure; as also the Cylindrical Weight of the same taken at every Yard in Length.

Cub. in Inches Square.			Averdupois Weight.			Dit. in Pounds.			Cylin. in Inches Square.			Averdupois Weight.			Dit. in Pounds.		
Inch.	Ounces.	Parts.	Lib.	Oz.	Parts.	Lib.	Oz.	Parts.	Inch.	Ounces.	Parts.	Lib.	Oz.	Parts.	Lib.	Oz.	Parts.
1	20	86279	1	4	86, 0c.	1	4	86, 0c.	1	16	34933	1	0	34, 0c.	1	0	34, 0c.
1½	41	72558	2	9	72, 0c.	2	9	72, 0c.	1½	32	49867	2	0	49, 0c.	2	0	49, 0c.
2	83	55116	5	3	55, 0c.	5	3	55, 0c.	2	62	50440	3	12	50, 0c.	3	12	50, 0c.
2½	125	17674	7	13	17, 0c.	7	13	17, 0c.	2½	98	35313	6	2	35, 0c.	6	2	35, 0c.
3	187	76511	11	11	76, 0c.	11	11	76, 0c.	3	147	52658	9	3	52, 0c.	9	3	52, 0c.
3½	250	35340	15	10	35, 0c.	15	10	35, 0c.	3½	196	37764	12	4	37, 0c.	12	4	37, 0c.
4	333	70464	20	13	70, 0c.	20	13	70, 0c.	4	262	19621	16	6	19, 0c.	16	6	19, 0c.
4½	417	25580	26	1	15, 0c.	26	1	15, 0c.	4½	327	84341	20	7	84, 0c.	20	7	84, 0c.
5	521	56975	31	9	56, 0c.	31	9	56, 0c.	5	409	80400	25	9	80, 0c.	25	9	80, 0c.
5½	625	88370	39	1	88, 0c.	39	1	88, 0c.	5½	491	76571	34	7	75, 0c.	34	7	75, 0c.
6	749	06064	46	13	06, 0c.	46	13	06, 0c.	6	588	54782	36	13	54, 0c.	36	13	54, 0c.
6½	876	23718	54	12	23, 0c.	54	12	23, 0c.	6½	688	47207	43	0	47, 0c.	43	0	47, 0c.
7	1024	17671	64	0	17, 0c.	64	0	17, 0c.	7	804	71027	50	4	71, 0c.	50	4	71, 0c.
7½	1168	30594	73	0	30, 0c.	73	0	30, 0c.	7½	917	95481	57	5	95, 0c.	57	5	95, 0c.
8	1335	21856	83	7	21, 0c.	83	7	21, 0c.	8	1049	10029	65	9	10, 0c.	65	9	10, 0c.
8½	1502	12088	93	14	12, 0c.	93	14	12, 0c.	8½	1180	23312	73	12	23, 0c.	73	12	23, 0c.
9	1689	88529	105	9	88, 0c.	105	9	88, 0c.	9	1327	76756	82	15	76, 0c.	82	15	76, 0c.
9½	1877	65110	116	1	65, 0c.	116	1	65, 0c.	9½	1475	11570	92	3	11, 0c.	92	3	11, 0c.
10	2086	27900	130	6	27, 0c.	130	6	27, 0c.	10	1634	21921	102	2	21, 0c.	102	2	21, 0c.
10½	2294	90690	143	6	90, 0c.	143	6	90, 0c.	10½	1803	13685	113	15	13, 0c.	113	15	13, 0c.
11	2524	39759	157	12	39, 0c.	157	12	39, 0c.	11	1912	02667	119	8	02, 0c.	119	8	02, 0c.
11½	2753	88828	172	1	88, 0c.	172	1	88, 0c.	11½	2163	29793	135	3	29, 0c.	135	3	29, 0c.
12	3004	24176	187	12	24, 0c.	187	12	24, 0c.	12	2317	61852	144	13	61, 0c.	144	13	61, 0c.

THE Use of this Table is so plain, that I need not enlarge much upon it; for supposing you have 760 Yards of Square, or in this Place we will rather say, Circular Pipe of seven Inches and a half Diameter, it is plain that a Yard in Length of Water within such a Pipe

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Pipe weighs fifty-seven Pounds, five Ounces, ninety-five Parts : This may be multiplied by 760 ; but because those odd Measures and Fractions will create much Trouble, I have chose rather to multiply the 917 Ounces, 95481 Parts, by 750 as is shewn in the Example.

Ounces	Parts	
917	95481	
	760	
5507728860		
642568367		
16) 69764565560	Pounds	Parts
	(43602	85347
57		Something more than
		half a Pound.
96		
045		
136		
85		
55		
76		
120		
8		

C H A P. XXXV.

Of artificial Fountains, Jets d'Eau, &c.

A GREEABLE to what has been before treated of, those who have wrote of the Theory and Conduct of Water for Reservoirs, Fountains, &c. have endeavoured to explain themselves in about twenty Propositions ; which, like so many Maxims, serve for the Foundation of all that can be said on the Rising or Spouting of Water in Fountains ; and they are chiefly these.

PROP.

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PROP. I. *That Air may be compressed, but not Water.*

PROP. II. *That Water cannot enter into a Vessel, but there must come forth as much Air, except the Water be sent in by Force.*

PROP. III. *From whence it follows, by the contrary Reason, (as de CAUS has it,) that if a Vessel be full of Water, it cannot be emptied, so as that the Air shall not enter therein.*

PROP. IV. *That there can be no Vacuum, or Space, entirely devoid of Matter (though there may be a dispers'd Vacuum) in the World.*

PROP. V. *If Air be pressed into a Vessel wherein there is Water, and that you give it Passage by some Pipe, the said Water shall come forth with Violence.*

PROP. VI. *That Water weighs upon that which sustaineth it according to its Height.*

PROP. VII. *That Water naturally ascends to the Level of the Place from whence it did descend.*

By these and some other Propositions it is, that the Rise of Water in Syphons, Syringes, Fountains, &c. are demonstrated, which I shall not here consider separately, but take a short View of Air, which by its Gravity, Elasticity, and Impulse, agitates Water and other Fluids; referring my Reader for his fuller Directions in this Matter to those Chapters where the Gravity, Elasticity, and Impulse of Air, are more fully handled.

LET A B C D Fig. I. Tab. seq. be a Vessel filled to the Brim with Water, and in it let there be placed a Curve Tube, or Syphon, E G H K, likewise full of Water, the Orifice whereof I K is for that Purpose stopp'd with the Finger or otherwise. If now you remove your Finger from I K, every Body knows experimentally, that the Water will run out from I K to Z, rising up in the mean Time in that Part of the Syphon E G which is shortest, and coming down in the longest H K, as long as the Water in the Vessel continues higher than the Mouth of the shortest Leg E F.

Now to know the Force and Manner whereby this Operation is brought about, stop the Syphon again with your Finger at I K,
by

by which Means the Water in that, and in the Vessel will stagnate. Suppose then X to be the upper Place of the Air, which presses here upon the Water, and produces the horizontal Plane of the Water, AD , throws PQ to RS whereof LM , NO , PQ , and RS , are equal Parts; and thereupon, according to the preceding Rules, the Part LM will be pressed with the Weight of Air gravitating thereupon.

SUPPOSE the Pressure LM , to be a hundred Pounds, the Water Column $PQIK$ by b , of ten Pounds; and that of the Air $RSTV$, being of the same Height, by c , of one Pound: Now since LM , NO , PQ , which are equal Parts of the same horizontal Plane AQ , and all Water; and to all which we may suppose, that a Line or Thread may be drawn without passing through a solid Body, or any other Fluid besides Water; and since by the Action of the Syphon, the Plane LM moves, or is pressed downwards, that of NO upwards, and that of PQ again downwards; if every Thing be reduced to rest by stopping the Orifice IK , the Powers whereby the said Planes were pressed upward and downwards will be equal, and LM being pressed downwards, by the Weight of the Air Column LWM , that is by a , or a hundred Pound, NO will be pressed upwards and PQ downwards by the same.

IF we now join to the Weight of this Air Column of a , or one hundred Pounds, which presses PQ downwards, the Water Column QIK of b , or ten Pounds, by which IK is likewise pressed downwards, the Force or Weight which presses IK , will consist of a join'd to b , or of one hundred Pounds, and ten Pounds, to wit, of the Air and Water Columns together. And so, it is with this Force that the Water gravitates downwards to Z . If now the horizontal Plane passing through IK be extended to V , and TV suppos'd equal to IK , then will TV be press'd downwards by the whole Column of Air IVX , that is, by RSX of a , or one hundred Pounds, (the same being equal to LMV ,) and by $RSTV$ of c , or one Pound, that is, of a and c , or one hundred Pounds, and one Pound join'd together. Now just so much Force is the Part IK , or rather the Air pressing against IK , or the Finger, (if we don't consider the Thickness thereof press'd upwards,) so that here is seen two Powers pressing against each other on IK , or the Separation of Air and Water operating and acting against each other; and the Fact is obvious to any one.

Marriotte, Part IV. *Disc.* 1. of his *Hydrostaticks*, tells us; that the like Effects will follow from Weights put upon a Syringe. For Example, Let *ABCD*, *Fig. 2. Tab. seq.* be a Syringe of three Inches diameter, having at its Passage a Bore of four Lines at *E*, the Piston is *FG*, which has a Plate below its Handle, to which it is fix'd, that the Syringe may be kept upright, the Piston being just within; there is Water pour'd in, to fill from the Height of the Piston *L*, as far as *E*; *MN*, *OP*, are two Sticks fix'd to the Body of the Syringe, on which hang two equal Weights *Q* and *R*, with two Cords on each Side of the Syringe. I say, that if these two Weights, which we may suppose to be Air, weigh twenty Pounds, any Jet will spout through *E*, as high as by any of the receiv'd Laws of *Hydrostaticks* it would, (if it were so much incumbent Air,) and would produce the same Effects, though it were in *Vacuo*. What any additional Weight would effect, or how much higher they would raise the Water in larger Tubes, is fully prov'd by *Marriotte* in *Fig. 83, 84, 85.* of the aforesaid Discourses, to which I refer my Reader.

THE Observations made on this Head by the aforesaid very curious Author, have produc'd a Machine, which he calls *Fons Hero-nis*, or *Hero's Fountain*, describ'd in his Treatise *De Spiritualibus*, according to the Translation of *Commandinus*, which take as follows.

LET *EFGH* (*Fig. 3. Tab. seq.*) be a Machine full of Water, as far as the Line *IL*, a little below *EF*; and a Pipe *MN*, which is well folder'd at *M* and *O* to the two Plates *EF*, *GH*, which make the Top and Bottom of the Trunk, to hinder the Air from going into it. The Trunk *EG* will serve for a Cistern or Reservoir.

It is necessary, however, that there should be another Trunk equal to the first, as *CDIK*, full of Air, to which the Pipe *MN* may be folder'd. When we pour the Water through *M*, it will go down through *N*, as far as *KI*; and being risen up as far as *PQ*, the Air contain'd in the Space *QPCD*, and in the Pipe *XY*, open at *X*, and well folder'd to the two Trunks, will not be able to go out through *A*, and will be condens'd by Degrees, till there be made an *Æquilibrium* between the Weight of Water in *MN*, and the Spring of the included Air.

FOR

FOR Example: If the Water be rais'd to R S, the Air contain'd in the Space C D S R in the Pipe X Y, and in the Space E I F L, will be condens'd by the Weight of the Water M S, and will press the Water I H G L; then if we open the Adjutage A, whose Pipe descends near H G towards V, the Water will spout to the Height A Z, very near equal to the Height M S, because the Air which is press'd by the Height of the Water M S makes the same Effort upon the Water I G, as if the Pipe M S, (full of Water,) was above the Water I L; and the Water which shall fall from the Jet, passing through M will re-enter into the lower Trunk; and by this Means the Jet will last till all the Water, (which reach'd from the Extremity V, of the Pipe A V, to the Extremity Y of the Pipe X Y) be gone out in spouting.

IF in this Place we should consider Water, not only as to its Rise, but the Beauty it is to afford in Fountains, certain it is, that the Beauty of it consists in that Uniformity and Transparency which it affords at the going out of the Adjutage, of which there are several kinds, as being subject to the least Friction of any yet contriv'd; but of this more in its proper Place.

ACCORDING to what has been before set down, Water will not rise higher, if so high, as the Fountain which supplies it; but however, there are Methods whereby Water in artificial Fountains may be made to rise higher than the Water in the Reservoirs or Cisterns which supply them, without any Means whatsoever, save the Gravity and Weight of Water itself.

LET A B C D, *Fig. 4. Tab. seq.* be an open Cistern, from which an open Tube N R is carried downwards, through the Covering E H of another Cistern E F G H, shut so close, that no Air can get in, passing down to R, almost to the Bottom of the Cistern F G.

FROM the upper Part of this lowest Cistern E H, there arises a second Tube S T, passing on almost as high as T D, or the Lid of a second Cistern D C K I, which is likewise closed; and from thence there is again deriv'd a third Tube to L M Q, which is stopp'd with a Cock, which has a large Orifice at M O. Moreover, in the Cistern D C K I there is a Hole at P, which can be open'd and shut by another Cock or Stopper.

To set this Machine to work, pour in Water at the Orifice P into the Cistern DCKI, till the Tube LZQO be full; shut the Cock MO, continuing to pour Water in at P, till the Water rises in the said Cistern to the Height TY, or level with the Mouth of the Tube T; then shut the Cock P, and pour in Water to the Cistern till it rises to the Height 2 T. This is not indeed absolutely necessary here, but is prescrib'd, to the End that by taking the Height of the same Water in both the upper Cisterns, the Calculation may be the more simple, and consequently the more intelligible to unexperienc'd Persons.

This being done, and every Thing at Rest, upon the Opening MO you will see the Stream of Water rising up to V, through the middle Orifice of the Plate 5, 6. or at least to a considerable Height above the uppermost Superficies 2 T of the Water which is in the Cistern ABCD and DCKI, and which presses upon the Stream 6 V. And in this Place it must be observ'd, that forasmuch as the Water of the upper Cistern ABCD descends into the lower EFGH during the Play of the Fountain, there must be a Hole in the latter, from whence the Water may be discharg'd; which being done, it must be stopp'd up again, if you play the Fountain in the Manner you did before; or otherwise you may place a little Pump at 2 through the Tube NR, down to the Bottom FG, and then pump the Water out of the lower Cistern EFGH through N, the Cock being open'd in the Cistern DCKI.

WE have already given an Account of the Fountain of *Hero Alexandrinus*, as describ'd by *Marriotte* with some Improvement. But whereas, in that of *Hero* it is not possible to make that which spouts out to attain to a Height equal to that of the Fall; but in this, notwithstanding the Height of the Machine was no more than three Foot and a half, the Jet rose five Foot higher than the Water in the upper Cistern.

LET GA FH *Fig. 5. Tab. seq.* be the uppermost Cistern, lying open, and having under it two smaller, and every where Air-tight Cisterns ABCD and DCEF; each of those has an Orifice or Hole, one at M, and the other at N, and both of them may be render'd also Air-tight, by stopping them with a Cock, cover'd with a wet Bladder, or a Cock. There are likewise two close Cisterns below STRP and PRQO. From the Bottom AF of the uppermost Cistern GA FH, there passes a Tube KI downwards

wards almost to the Bottom *R T* of the Cistern *P R S T*, but in such a Manner, that the same, or whatever it contains, has no Communication with the Cistern *D C E F*, through which it passes. And from 3 in *P S*, there is carried a Tube 3 *L* upwards, just below the uppermost Plane *D F* of the Cistern *D C E F*; from the Bottom of which *C E* there descends again at 9 a Tube at 9 *b*, terminating in the other Cistern *Q O P R*, very near the Bottom of it *Q R*; and this same Cistern *Q O P R* sends again a Tube 4 *Z* upwards, which beginning at 4, is carried on to *Z*, exactly under the uppermost Plane *A D* of the Cistern *A B C D*. Lastly, at *A D* there is a Tube *p r*, close folder'd at 5, 6, which rises to *r b* only, or a very little higher than the Plane *A D*, and passes downwards to *P*, or nearer to the Bottom *B C*.

On the Top of this last Tube another was fix'd *r 8*, which at *W 8* was cover'd with a flat Plate, having a small round Hole in the Middle of it, through which the Stream was to pass, which was closed at the Joint *R* with the finest Plaister, so that it was impervious either to Water or Air.

Now to work this Machine it is to be turn'd upside down, so that the Cistern *G A F H* be undermost, and having fill'd both the Cisterns *A B C D* and *D C E F* with Water at the Orifices *M* and *N*, the said Orifices are to be stopp'd with a Cork and Bladder, putting a Finger in the mean Time upon the Hole in the little Plate *W 8*, to the End that the Water pour'd in at *M*, or so much of it as was above *p*, might not run out.

It will not be necessary to give an Account here, how the Water subsiding or sinking from *G A F H*, through the Tube *K I* presses the Air out of the Cistern *P R S T* through the Tub 3 *L* upwards, which finding no Room any where but by pressing downwards, the Water in the Cistern *D C E F*, protrudes the said Water towards the Cistern *O Q R P*, with much greater Force than that of its own or single Gravity. At which Place the Water likewise ascending, the Air is protruded with the same Force from *O Q R P*, through 4 *Z* to the Cistern *A B C D*, which causes the Water to spring out of the Tube *p 8* after this Manner, with almost the Force of both the Weights of the Water Columns *Y H* and *K I*; and in this Manner may be deduc'd the Operations of the foregoing Fountains, Syphons, &c. without any Calculation. Nor will it be difficult to any one that understands this aright, to cause a Stream of Water to rise up to any given Height by a requisite Multi-

Multiplication of Cisterns and Tubes, the Height of the Descent of Water being likewise given, as may be seen in *Bockler's* elaborate Treatise of *Architecture* and *Hydrostaticks*, which I have much Occasion to consult in this and the following Volumes.

BUT to finish this Account: The Machine we have been just giving an Account of, may be improv'd in such a Manner, as not to have Occasion to invert it, nor yet stop the little Hole of the Column W 8, with the Finger, or any Thing else, by Stop Cocks in other proper Places, and by making the Orifices M N, above at A F, as is known to every Body that has any Skill in these and other kinds of Water-Works.

Fig. 6. Tab. seq. is a Scheme wherein the Motion of Water in a Curve Tube is describ'd, of which more in its proper Place.

AND *Fig. 7. Tab. seq.* is the compleat compound Fountain of *Hero's*, as describ'd by *Gravesande*, the Construction of which is very plain and obvious.

CHAP. XXXVI.

Of the Construction and Use of a Gauge for Measuring of Water, and of the Distribution and Expence of it to Cities, Towns, Gardens, &c.

AMONGST the Works of the celebrated *La Bion*, I find a Gauge, which he appears to have taken from *Marriotte*, for to know the Quantity of Water which a Source furnishes, which is of a Rectangular Paralleloepidon of Brass well solder'd, about a Foot long, eight Inches broad, and as many in Height, more or less, according to the Quantity of Water to be measured, having several round Holes very exactly drill'd in it, at an Inch in Diameter; and others for half an Inch of Water to pass through; and also others for a Quarter of an Inch of Water to pass through them: All which ought to be drill'd, so as that their Centers may be of the same Height. The upper Extrems of the Inch-Holes must be within two Lines of the Top of the Gauge; and the Holes are
stopped

stopped with little Brass square Plates, adjusted in the Grooves, 1, 2, and 3. There is Brass Partition crossing the Vessel mark'd 4. fix'd about an Inch above from the Bottom, and drill'd with several Holes to make the Water pass more freely. This Partition is made to receive the Shock of the Water falling from the Source into the Gauge, and hindering it from making of Waves; so that it may the more naturally run out through the Holes; where note, that to give a cylindrick Inch of Water you ought to allow twelve Lines in Diameter, that giving half an Inch ought to be eight Lines one Half; and that giving a Quarter of an Inch ought to be exactly six Lines: All which may be found by Calculation.

To use the Instrument, it must be placed, so as that its Bottom may be parallel to the Horizon; and then let the Water of the Spring or Source run through a Pipe into the Gauge, (as by the Figure,) and when it wants about a Line of the Top, open one of the Holes (for Example) of an Inch: Then if the Water always keeps the same Height in the Gauge, it is manifest that there runs as much into it, as goes out of it; and so the Spring or Source will furnish an Inch of Water: But if the Water in the Gauge rises, there must be another Hole open'd, either of an Inch, Half an Inch, or a Quarter of an Inch Diameter; so that the Water may keep to the same Height in the Gauge, that is, to a Line above the Holes of an Inch, and then the Number of Holes opened will give the Quantity of Water furnished by the Source or Spring.

THE little Vessel receiving the Water running out of the Gauge, is to shew how much Water the Spring furnishes in a determinate Space of Time; for having a Pendulum, which swings Seconds, note how many Seconds there will be in the Time that this Vessel, set under the Hole, giving an Inch of Water, is filling; and exactly Measuring the Quantity of Water it contains, you may know the Quantity of Water the Spring or Source furnishes in an Hour.

THERE have been several exact Experiments made upon this Subject, (which have been set down before in this Treatise,) from whence, as has been before observed, one Inch of Water will fill fourteen Pints of *Paris* Measure: But of this so much has been said already that I need not repeat it.

To measure the running Water of our Aquaduct or River, which cannot be received into a Gauge, you must put a Ball of Wax upon the Water, made so heavy with some other Matter, as that there may be but a small Part of the Ball above the Surface of the Water, that so the Wind can have no Power of it:
And,

And, after having measured a Length of fifteen or twenty Foot of the Aquaduct, you may know by a Pendulum, in what Time the Ball of Wax will be carried that Distance; and afterwards multiplying the Breadth of the Aquaduct or River by the Height of the Water, and that Product, by the Space which the Ball has moved, this last Product will give all the Water passed in the noted Time through the Section of the River, (as has been elsewhere observ'd.)

To come to Example: Suppose that in an Aquaduct two Foot wide, and one Foot deep, a Ball of Wax moves in twenty Seconds thirty Foot; which will be one Foot an half in a Second: But because the Water moves swifter at the Top than at the Bottom, you must take but twenty Foot, which will be one Foot in a Second: The Product of one Foot deep by two Foot broad, is two Foot; which multiplied by twenty Foot, the Length, gives forty cubick Feet, or forty Times thirty-five Pints *French* Measure of Water, which makes fourteen hundred Pints in twenty Seconds: And if twenty Seconds give fourteen hundred Pints, sixty Seconds will give 4200 Pints, and dividing 4200 by 14, which is the Number of Pints an Inch of Water gives in a Minute or sixty Seconds, the Quotient 300 will be the Number of Inches, which the Water of the Aquaduct furnishes. And thus much I thought proper to insert in this Place, though it be a kind of Repetition of what is gone before. And now I proceed to the Manner and Method of Distributing of Water for the Supply of Cities, Towns, Gardens, &c.

SEVERAL are the Methods which I have observed, that Fountain-Makers, and Water-Workmen use in this Affair; but none are so exact as those which the curious *Marriotte* makes use of.

HITHERTO we have treated concerning the Coming in of Water only; it now remains that we treat of the Expence or Going out of it, as it relates to the furnishing Houses and Gardens, which depend very much, if not altogether, on the Rules before going.

IF, therefore, a Spring such as is that of the Town of *Chelmsford* in *Essex*, happens to the Lot of any Gentleman, or of any Society of People in a City, what may not such Person or Persons do, either as to the Supply of Buildings, Fountains, or Cascades: Since by several Experiments that have been there made with great Care, that Spring from a five Inch Main, whose Content is twenty-five Inches square, produces 12272 Hogsheads, 48 Gallons in one Day; which will be sufficient for any large Family with their Gardens, &c. or even any Town Corporate, that is not very large indeed; especially if it is conducted into a Reservoir, and distributed

puted as it is occasionally wanted, into the several Parts of the Houses and Gardens of such Places.

It will be impossible to calculate the various Uses to which this Water may be applied, or the Manner how, in as much as it depends on the Sizes of your Pipes, and the Jets or Sheets of Water it is to supply; however the following Account may serve to give some Insight into what I am now putting down.

SUPPOSING then that you have Cocks to supply in the House, two of two Inches Diameter, two of one Inch and an half, two of one Inch, and two of half an Inch; for one or more of these Sizes are always wanted.

SUPPOSE also that you have as many Pipes to supply in the Garden, and that there are Cascades of thirty Foot wide in Addition to it; the great Question is how big, or, in other Words, how many Inches Diameter must a Pipe of Conduct be, that is to supply them constantly and upon all Occasions; because it would be a considerable Detriment to the Uses of your House, as well as Beauty of your Gardens, if they cannot be supplied all at one Time. Your Method must be thus.

	Inches Square.
The Two Pipes of two Inches Diameter each amounts to	8
The two of one Inch and an Half Diameter.	4
The two of one Inch	2
The two of half an Inch	1
Now all these added together makes	15
And the same repeated makes	30
To which, if you add the Width of the Cascade of thirty Foot, at half an Inch Thickness of Water, which is thick enough, the Account will be	180
In all	210

THE Square Root whereof being fourteen Inches and an Half, so much must the Pipe of Conduct be that is to supply such a Demand; and so much ought a Spring to give: But as there are few Fountains, which play Day and Night; and as there are few Offices or Buildings that are in continual Want of Water when there is a good

Reservoir made before-hand, where the Water is to lodge, a Spring of ten Inches will supply them all a whole Day; and as they are but occasionally used, suppose two whole Hours in a Day, (which is generally the most that they are,) a Spring of four Inches will be sufficient; but then the main Pipe which goes out of the Reservoir must be fourteen Inches, as above.

AGAIN it is necessary to come to a nearer Calculation than Ordinary where the Springs are but penurious, or you are supply'd by an Engine.

IT is certain that half an Inch Pipe is sufficient for most small Families, and for all the Offices of a House, except the Brew-House, or Wash House, which ought to be at least one Inch Diameter; when I say half an Inch I mean six Lines, which gives but a Quarter of the Water which a Pipe of one Inch or twelve Lines does, which is all I think requisite to add in this Matter; because every Owner of a Family may by a little Observation know what Quantity of Water he shall want in a Day or a Week, taking one Time with another, better than any Calculator possibly can.

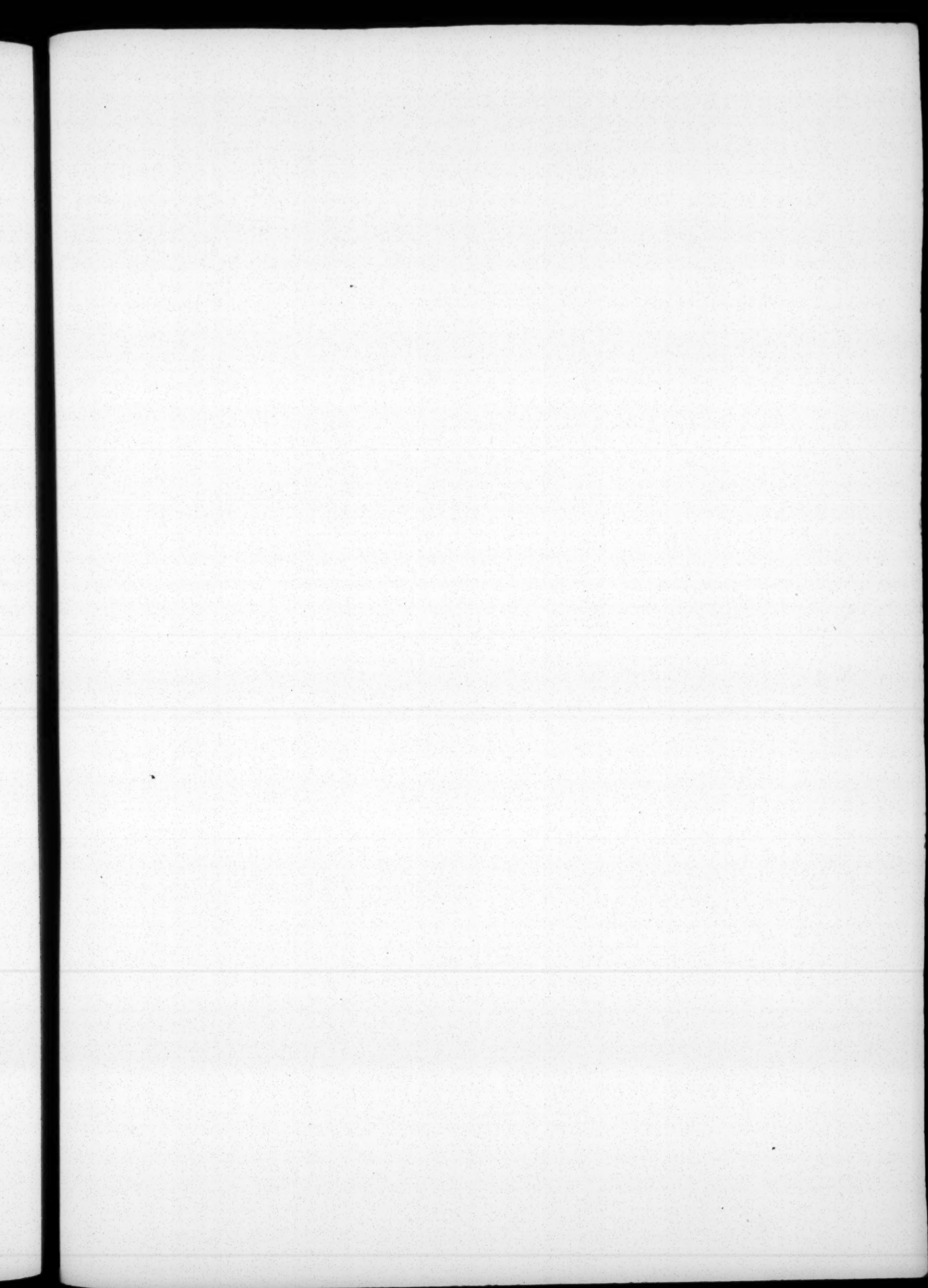
C H A P. XXXVII.

A Description of the Thirty last Plates.

PLATE XXXI. This Plate is a Plan which belongs to the Perspective of Plate XXXIII. wherein is seen not only the Water, but the Walk on each Side, with the Pedestals, which represent the Cypress Trees, which see in the Perspective, together with the square Troughs in the Hills, out of which the said Water is made by Nature to spring out of the Hill, and is delivered after its Passage through a Canal of a Length undeterminate over the Cascade, or Head of Water.

THE Plan was originally designed for a Gentleman in the West, which might, at a reasonable Expence, have been executed, and is here produc'd as a Specimen of this Kind of Work. The farther Particulars whereof will be inserted in the thirty third Plate, after I have given a short Account of the next, which relates in a very particular Manner to the Calculation and Expence of Water over the Heads of Cascades.

PLATE



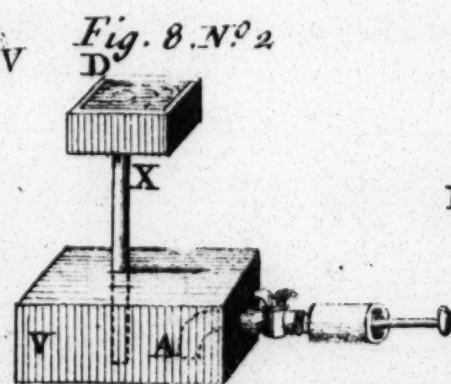
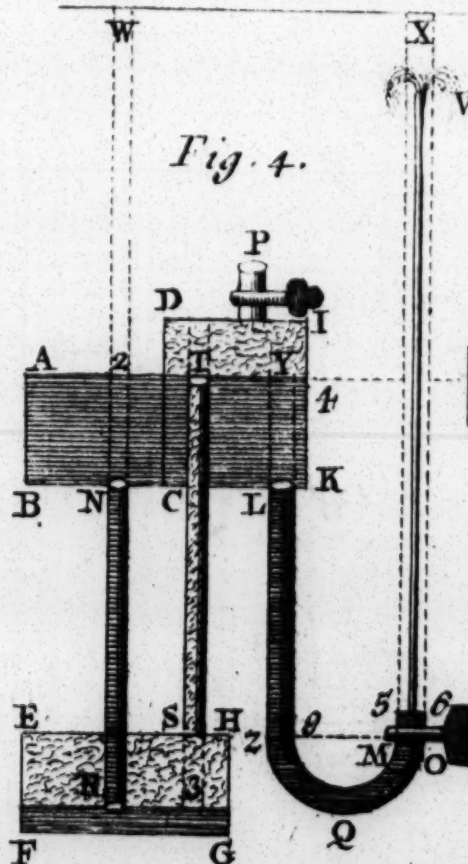
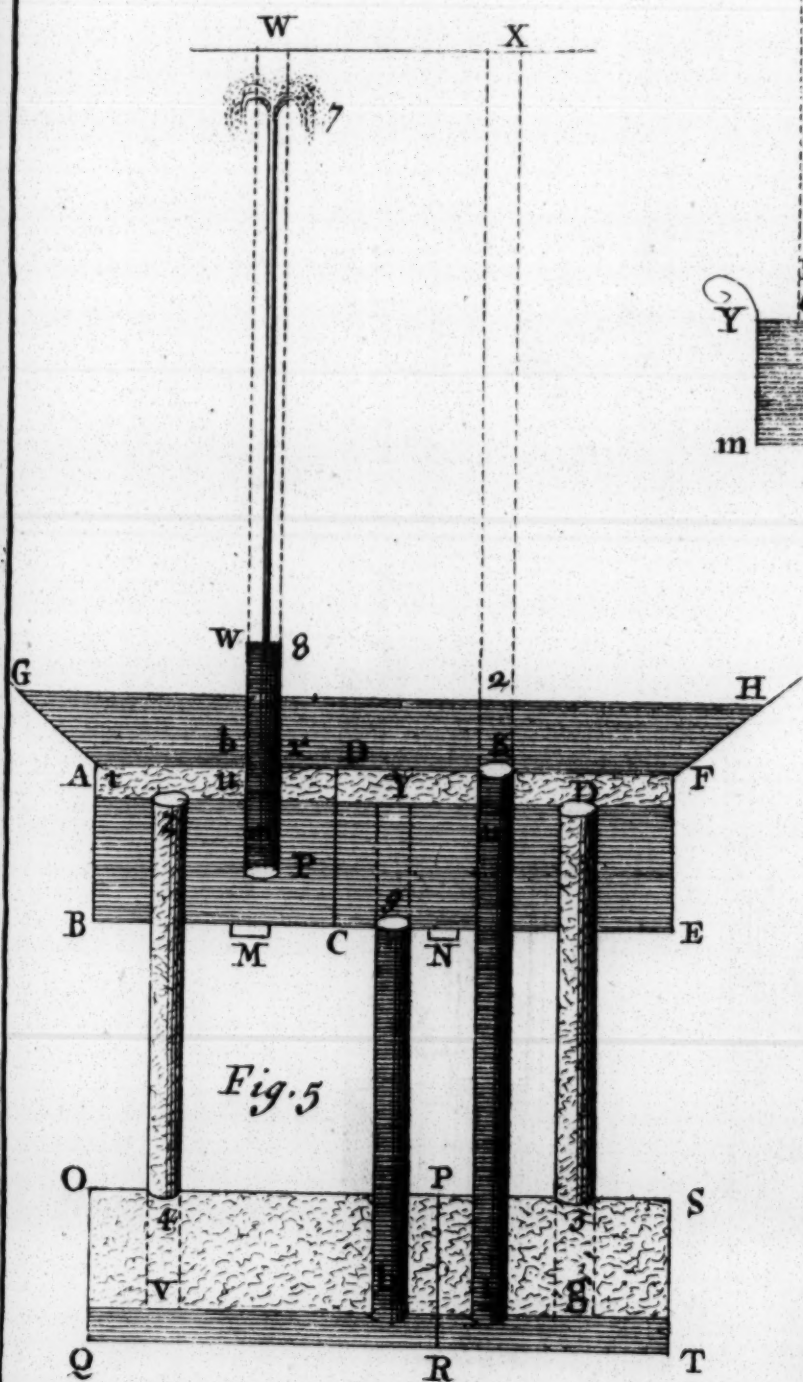
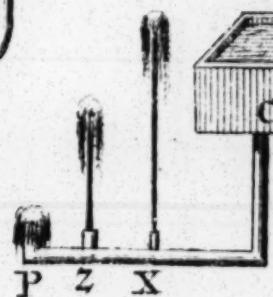
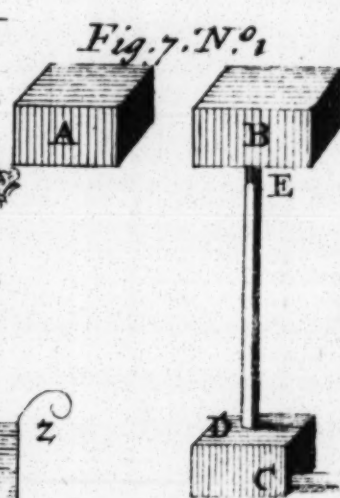
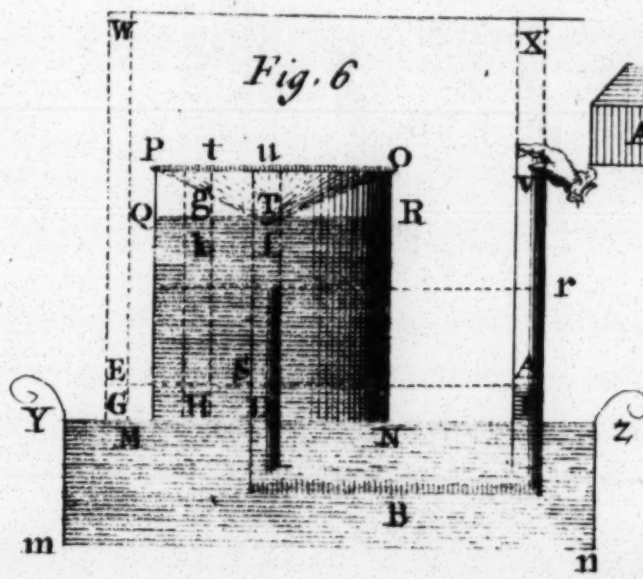
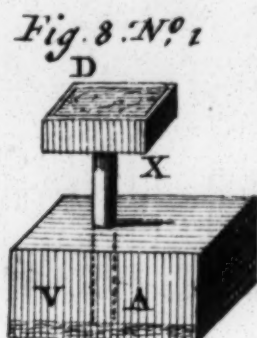
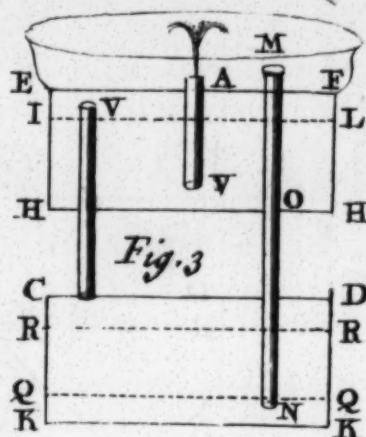
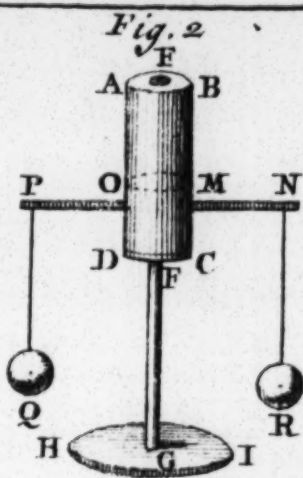
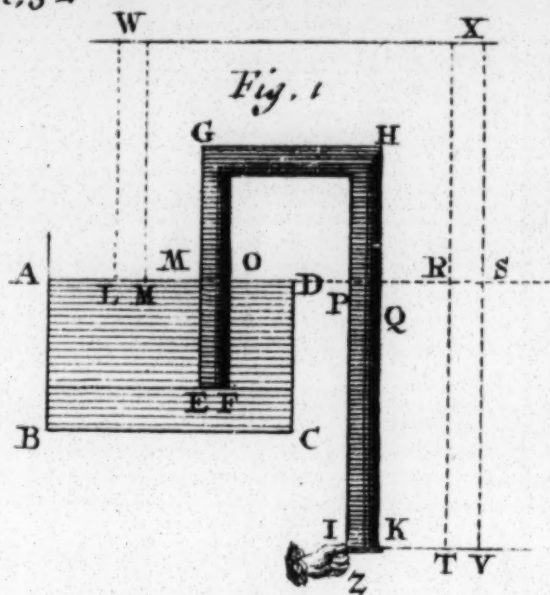


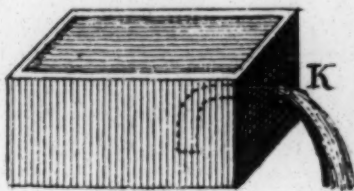
Fig. 13



Fig. 16
N^o 1



N^o 2



N^o 3

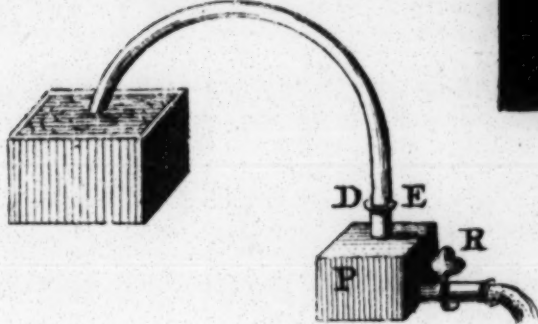


Fig. 22

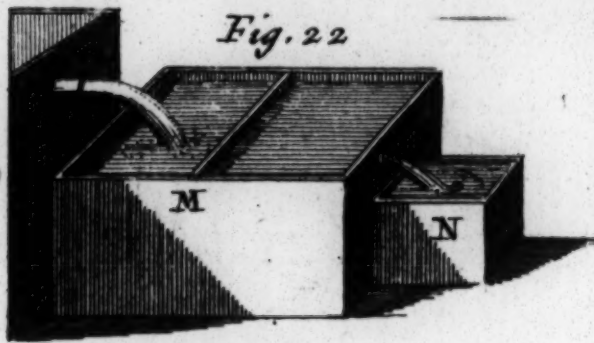


Fig. 21

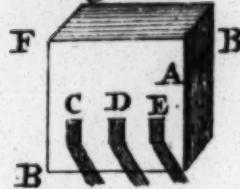
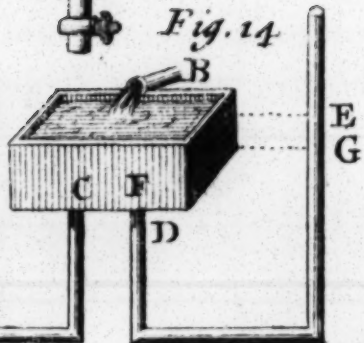


Fig. 20

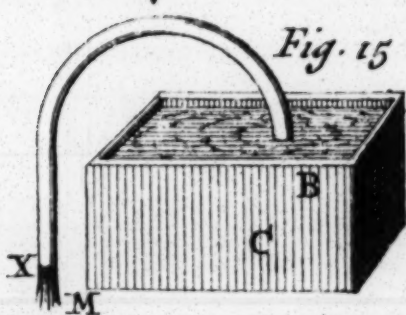


Fig. 14



V

Fig. 15



N^o 1.

Fig. 17

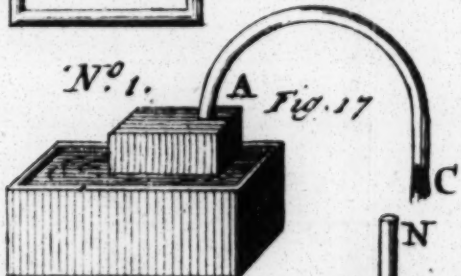


Fig. 17 N^o 2

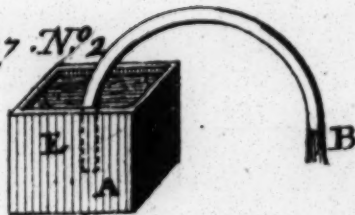


Fig. 19

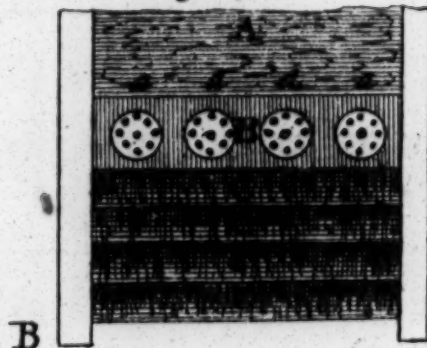
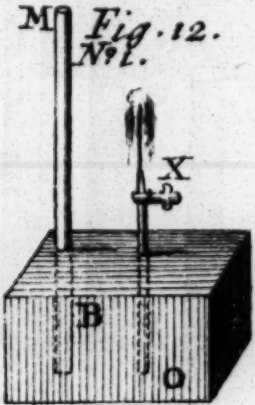


Fig. 12.
N^o 1.



P

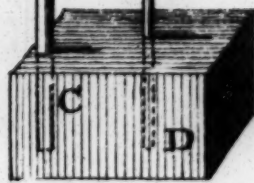
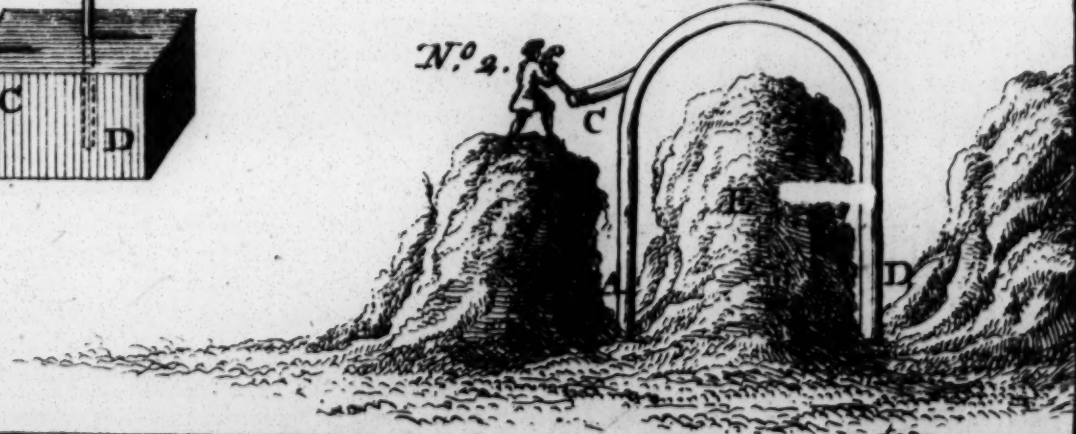
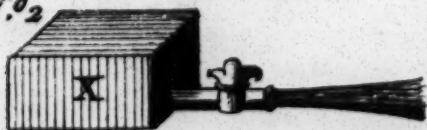


Fig. 18

N^o 2.



N^o 2





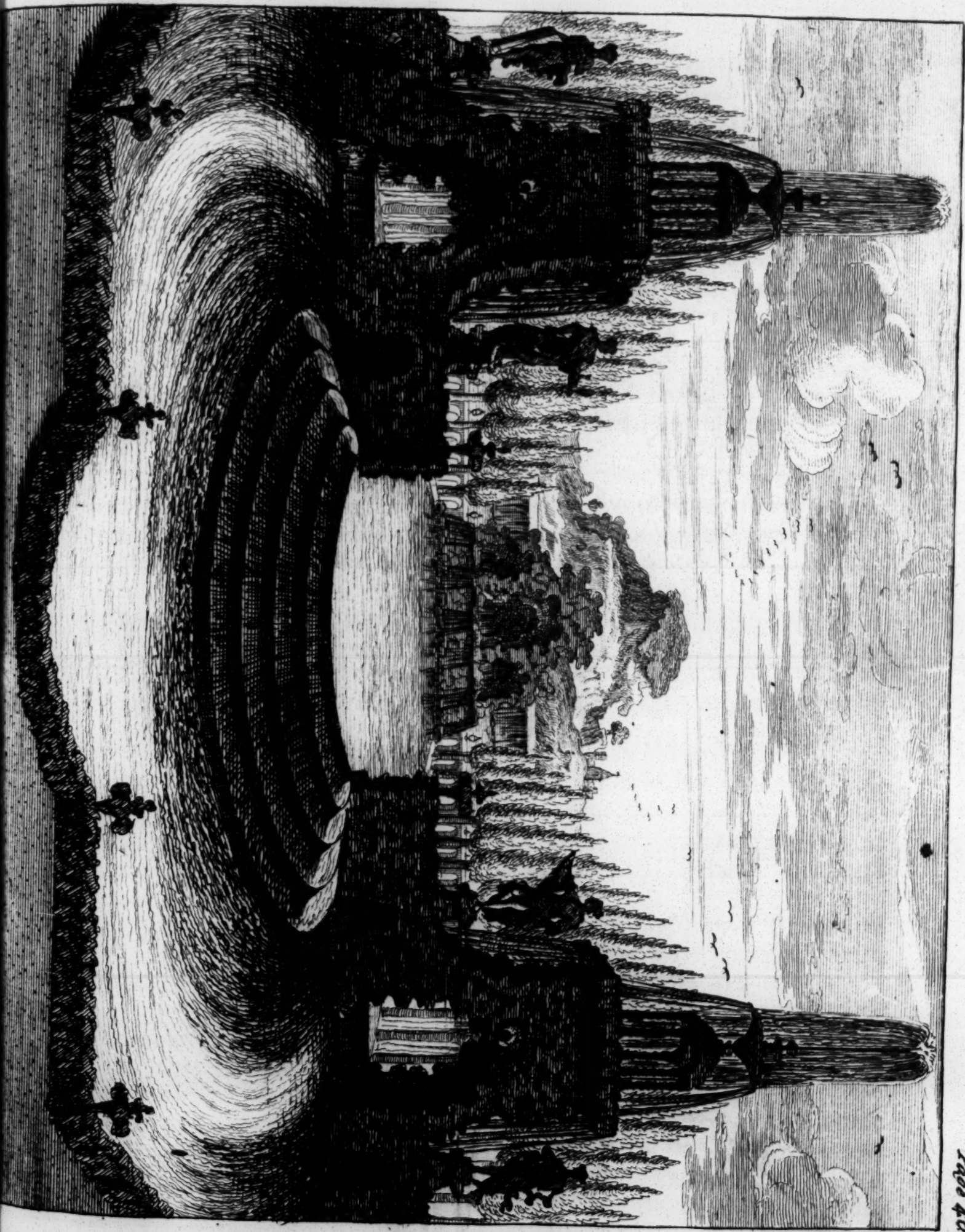




PLATE XXXII. The Description of this thirty-second Plate is more fully found in the Chapter foregoing, wherein are several Particulars which relate to the Passage of Water over Cascades, and Sewers of Water, which will there more plainly appear.

PLATE XXXIII. This thirty-third Plate is an Upright and Perspective of the thirty first foregoing ; for which I am obliged to my ingenious Friend Mons. *J. Devoto*, who has made a Collection of Drawings of this, and other Works of this Nature, in a Taste very agreeable to the Rural Way ; I have in this and several others of my Designs endeavoured to recommend a Design, which, I am almost bold enough to say, equals, if not exceeds, whatever has been produced either by the *French* or *Italians*.

THE Hills from whence the Water proceeds, represent themselves at a Distance, and are Reservoirs proper for the Delivery of such Water ; of which Hills there are some in the West, as well as many other Parts of *England* very suitable for such a Purpose ; of which the *Quantick* and other Hills in the County of *Somerset* and *Gloucester* are plain Proofs : And I must add that a Design of this kind must well have fitted the precipitate Falls of *Italy*, *Switzerland*, and other Places.

THE Steps are indeed drawn a little too smooth, but if the Water was conducted over a Cataract or rough Cascade, it would (in my humble Opinion) merit a Place prior to any Design produced in this or any Book of Water-works.

PLATE XXXIV. Is an Upright and Perspective of the Cascade at *Busby Park*, the real Design (at least the approved one) of that great *Mæcenas* of his Age, the late Earl of *Halifax*, whose true Taste in rural and extensive Gardening, I have long ago took Leave to celebrate.

THIS very handsome rural Design is supply'd by a Branch of the River *Colne* ; which, though not affording a perpetual Current, yet is never wanting to give Spectators a particular Pleasure.

THE Design is so well known, that I need not expatiate or enlarge upon it ; but is, however, of so rude and rustick a Manner that it may well serve as a Pattern or Model to any that shall be disposed to make use of Water-Works.

THERE is one Thing observable in the Judgment of the noble Lord before-mentioned, and which is his not endeavouring to crowd much Wood about this Cascade, as the *Italians* and *French*

do, inasmuch as it is in a Country where there is not so much Heat as there is in those just mentioned ; and this Consideration it is, that has very justly been the Occasion of some modern and very great Designers in Gardening, to make their Designs more open and freer from Cover ; because Water, however delightful it is, is apt (especially if in the Shade, and not clear) to detract greatly from the Beauty of it. And this, in my humble Opinion, is a very great Objection to the otherwise very pretty trifling Water-Works of my late deceased ingenious Friend, *John-Kyrle Ernly*, at *Sandy-Lane, Wilts.*

PLATE XXXV. The next Plate I produce, is from the *Italian* Fountains, and is called the Fountain of the Tower, situate in the Gardens of the *Vatican* at *Rome*, the Architecture of *Carlo Maderno*, and was, as appears by the Inscription, erected by that great High-Priest *Paulus V.* (*ad augendum Palatii Prospectus & Hortorum decorem*,) as that proud Gentleman on his Frontispiece has it.

THE good natured Reader will be so favourable as to observe, that I don't produce this Draught out of any great Ostentation as to its Beauty, but as it serves, (being of a *Portico* Construction) as a Forerunner to usher in the Draughts of some of the so-much-famed Water-Works of *Italy*.

PLATE XXXVI. The thirty-sixth Plate is a Fountain upon a Flat in the Wood, in the Gardens of *Belvedere* at *Frescati*, belonging to the so-much-famed Family of the *Aldobrandi* ; which being situate in Cover, and of Rustick Appointment can't (though small) be an inelegant Figure in Fact.

PLATE XXXVII. The Reader will probably wonder, that I have mix'd this Plan (which is purely *English*) amongst the Perspectives of *Italy* and *France* ; but so it is, that a Gentleman of pretended Honour, whom I shall not Name, gave me great Hopes of copying the Plans of the Water-Works of *Versailles* ; of which I intended to make the 31st, 32d, 34th, 35th, and 36th Plates, and to have let this follow them, that I might have made a Parallel of our *English* Way of Design, compar'd with that of *France*.

BUT as that Person (after long Promises) deceived me, and thereby hinder'd the Publication of some of the best Things amongst the *French* Water-Works, I was obliged to give those Plates the Turn they now have.

THE

THE upper Part of the Work may very easily be seen to be a Sketch of the fine Amphitheatre at *Claremont*, (belonging to his Grace the Duke of *Newcastle*) the Design of the very ingenious Mr. *Bridgeman*; and the lower Part, where the Water Spouts out, is an Addition of my own, from a Work of that kind that I have done for the Right Honourable the Earl of *Orrery*, at *Marston* in *Somersetshire*.

IN this Composition, which I humbly conceive to be the noblest of any in *Europe*, may be seen a very magnificent Taste and Way of thinking, and in which I can't help observing, that had the ingenious Designer had more Room at *Claremont*, he would certainly have made his Water much larger than that little Circular Basin, which is seen therein, and which is very much eclips'd by the prodigious Grandeur of that Amphitheatre. And this I note for the Advantage of those who have more Room for such a Purpose: As for the rest the Plan speaks for itself.

PLATE XXXVIII. The next Account to be given of the Plates placed at the End of this Book, is of some Designs of Water-Houses, Grots, &c. the first of which (Plate XXXVIII.) is amongst the Designs which are brought over from *France*, and carries with it the Title of *Cecropidarum Sacrilega Curiositas*, or the Sacrilegious Curiosity of the *Cecrops*, Daughters of *Ops* and *Terra*; of whom *Ovid* thus:

----- *Nam tempore quodam*
Pallas Erichthonium, prolem sine matre creatam,
Clauserat Aëlaeo texta de vimine cista,
Virginibusque tribus gemino de Cecrope natis
Hanc legem dederat, sua nè secreta viderent.
Abdita fronde levi densa speculabar ab ulmo,
Quid facerent: commissa duæ sine fraude tuentur
Pandrosos, atque Herse: timidas vocat una sorores
Aglaurus, nodosque manu diducit: at intus
Infantemque vident, apporrectumque draconem.

PLATE XXXIX. I shall not pretend to *English* nor enlarge on this Piece, but leave the Determination of the Design to the Curious Reader, and proceed to Plate XXXIX. which is taken from the same *Le Architect Paultre*, (by Mistake *la Nautre* on the Plate,) which is also from *Ovid. Met. Lib. III. ver. 407*. The Design is of *Narcissus* placed in a Nitch, who slighting *Eccho*, and falling

falling in Love with himself, is drawn above a Fountain with Water spouting out of the Heads of Dolphins underneath : Of which *Ovid* thus ; and which containing a Kind of rural Description, I insert at full Length.

*Fons erat illimis nitidis argenteus undis,
Quem neque pastores, neque pastæ monte capellæ
Contigerant, aliudve pecus ; quem nulla volucris,
Nec fera turbârat, nec lapsus ab arbore ramus :
Gramen erat circa, quod proximus humor alebat,
Sylvæque sole lacum passura tepecere nullo.
Hic puer & stadio venandi lassus & æstu,
Procubuit, faciémque loci, fontémque secutus :
Dúmque sitim sedare cupit, sitis altera crevit,
Dúmque bibit, visæ correptus imagine formæ,
Rem sine corpore amat, corpus putat esse quod umbra est.
Adstupet ipse sibi, vultúque immotus eodem
Heret : ut è pario formatum marmore signum, &c.*

PLATE XL. Is also another Design of *La Paultre's*, and is the Story of *Meleager* and *Atalanta*, *Ovid. Metam. Lib. VIII.* who is here represented with a Shaft of Arrows on her Back. This Design whether ever executed by the Architect, or no, I can't tell, is, I humbly suppose, amongst the most curious of all he designed. The Architecture on each Side is regular and just, and the rude Arch in the Middle, makes it, I think, one of the best Designs I have or shall produce.

My late good Friend *John-Kyrle Ernly*, at *Whettam* near *Sandy-Lane, Wilts*, on the Road to the *Bath*, had a Design at the Head of his long Cascade much like this, which has, in the Opinion of many good Judges, a very good Effect from the Bottom of it, only the Cascade is too narrow. And this brings me to the chief and best of the *French* Designs at *Versailles*, which for Expence or Costliness exceeds all the Water-Works of *Europe* if not the whole World.

PLATE XLI. This forty first Plate is taken out of a Collection of *French* Prints some Years ago engraved by the best Artists in the *Gobeline Square* ; and contains a View and Perspective of the Fountain of the Stars, situated in a little Wood ; in the Middle of which five Walks meet, which makes a Kind of Saloon of Forest Work.

THE Border of the Fountain is in Part done round with rustick Work ; but there are between those Works, (fronting the five Walks,) Openings over which the Water falls in the Nature of a Cascade or River. The Column of Water in the Middle breaks out also through a Mole or Heap of rustick Stones, as do all the Jets which break out on each Side ; and these Kinds of Designs I produce as the best amongst the Designs of the *French*, which are generally too regular and stiff, and adorned with too much Art.

PLATE XLII. The forty-second Plate is also call'd *La Fontaine d'Etoile*, or Fountain of the Star: And an Account of the Largeness of the Column of Water *La Montagne d'Eau*, or Mountain of Water at *Versailles*, and is on the same Side as the Theatre, in a little Wood in the Middle of five Allies, or Walks, border'd by a Kind of Saloon. The Water which spouts from this Fountain, is in the Shape of a great Mole, or Mountain, and falling again five Ways, forms so many Rivers, or Rivulets, which fall from the Foot of the Basin, into Alleys at equal Distances ; and in the Middle are Rocks which cast forth Water, very pleasant to the Curious Beholder.

PLATE XLIII. The next Plate I produce is a Perspective View of the Gallery of Water at *Versailles*, which being of so great a Number of Jets, or Pillars of Water, all in a Row on each Side, spouting up between Statues, make no inelegant Figure, though I humbly conceive it is not the finest Figure among the Water-Works of *Versailles*.

PLATE XLIV. Is a Perspective View of the three Fountains in the Gardens of *Versailles*, and which makes one of the finest Sights there, as well for the Disposition of the Water, as the situation of the Place itself.

THIS Place is near where there was formerly an Alley of Water arbor'd, or bower'd over, which the *French* call by the general Name of *Burcean*, and we in *England*, Cover'd Walks ; but is now laid open in a very elegant Manner ; and as the Jets spout up both in the Middle and in each Side, (as a Design of my own, which I shall by and by produce,) it can't but afford a fine View.

PLATE XLV. The forty fifth Plate is a Morass of Water in the Gardens of *Versailles*, situated at the End of a Flower-Garden, crossing the Alley of *Ceres* in a little Wood ; and is twelve Toises,
or

or seventy-two Foot long, and eight Toises, or forty-eight Foot wide. It is a Square of Water bounded with artificial Reeds, painted green, which all cast out Water. At the four Corners are four Swans, which cast out Water from their Bills. In the Middle is an Oak Tree, which casts out great Quantities of Water from its Branches; and on each Side of the Walk, which surrounds this Morass of Water, there is a Cavity, or Buffet, on which are placed gilt Vessels, and on each Side of them Spouts of Water, which in its Fall causes them to Glitter like Silver.

A DESIGN of this Kind I can't but recommend to the Curious, in as much as there is more of Nature in it, than in any of the *French* Designs, especially in the Middle of it.

FOR this Kind of Morass, or Fountain, set about with Water-Weeds, such as Water-Dock, Plantane, &c. being properly disposed in a low wet Place, and in hot Weather, answers all the Purposes that a Curious Beholder, (and one who makes Nature his Pattern,) can desire. How well those Kinds of Weeds and Flowers look when placed in the Middle of Water, any one may judge who ever saw that small Fountain which is in the Middle of a little Piece of Woodwork in *Trinity-College* Garden, *Oxford*; which, I think, deserves Imitation by all who make such like Basins and Contrivances for Water.

PLATE XLVI. The forty sixth Plate is a Perspective View of the *Bassin d'Amour*, or *Basin of Love*, more generally called the *Isle Royal*, which is in the Form of a Canal, in the Middle of which is an Island surrounded with eighty Water Spouts, which playing on all Sides hinders one from approaching it without being wet. It is placed on the Left Hand above the Labyrinth 130 Toises long, and 30 wide, and one Fathom deep, without reckoning those Pieces which were last made at the farther Ends. But for a more particular Description of this I refer my Reader to the Introduction to these Volumes, *Page 8*. these being the very best Pieces of Water amongst the *French*. I proceed to those of *Italy*.

PLATE XLVII. Is a fine Fountain in the *Esensian* Gardens at *Tivoli* in *Italy*, and is called the *Eagle-Fountain*, on Account of the carved Figures of those Birds, which spout Water out of their Mouths. The fine Rustick Mole of Stone, with the Water dashing or falling down on each Side, makes it very delightful not only in the Print, but Travellers, who have seen it, say, that in
Fact

Fact also, it is one of the best Pieces in the Gardens there. It is situate in the Middle of a Parterre of Flowers, and the Water plays at least forty Foot high.

PLATE XLVIII. Is a Fountain under a capital Arch in the Palace of Segnior *Massini*, the Architecture of the Chevalier *Carlo Fontana*, where the Water spouts through the Head of a large *Triton*, who is accompanied by *Dolphins* on each Side.

THIS Kind of Disposition must be very surprising, inasmuch as it is placed in so remarkable a Place as this Arch is; and I must own it is very much to be wonder'd at, that so august a Design as this is, has not met with more Imitators.

PLATE XLIX. Is a Prospect of the Theatre and Cascade of Water, which is in the *Villa Ludovisa*, in the *Frescati* Gardens; and which, for the Precipitancy of its Fall, and the noble Elegance of its Architecture, seems to be second to none of the *Italian* Designs, whether we account the Fineness of the Bullion or Spout of Water, which plays up in the Middle of the Rock-Work, over which the Water rolls: A noble Elegance of Taste, in which the *Italians* abound much more than the *French*.

PLATE L. Is a large Rustick Fountain in the Garden of Prince *Borghese*, without the *Porta Pinciana*, in the Front of the Gate, at the End of the Walk of Elms, and is called the *Fountain of the Masque*, the Architecture of *Giacomo Antonio Vensanti*. On this Fountain, which has an Arch under the great Masque, (through which the Rows of Elms may be view'd,) is seen lying one of the Sea Gods, pouring out of Water through an Urn, encompassed about with large Moles of rude unpolish'd Stone, through and over which the Water rises and falls in a very surprising Manner. This, as well as many other Pieces of their Water, is a true Specimen of the *Italian* Taste, which is not made up of Gewgaws and Trifles, as some in other Countries are.

PLATE LI. Is another Rustick Fountain in the Theatre of the *Villa Aldobrandina*, in the *Belvidere* Gardens at *Frescati*, which has Water-Works in the Stairs.

I SHALL not take upon me to make any Enlargement on this Design, although its Situation, which is amongst very large Trees, seems to make it look very rural.

PLATE LII. Is a Fountain in the Walk in the first Wall, which leads up to the *Franciscan Cloyster*, the Architecture of *Giacomo della Porta*, and is by some said to be the finest Sight of all the Water-Works of the *Frescati*, though I must own that there is nothing in the View of it in the Print, that seems to promise so great a Character, the most that one can collect from it being chiefly an Idea of some fine Grotto.

It is, as appears by the Inscription, not of a very antique Erection, no other than of *Clement VIII. Anno Domini 1603*. At each End, where the Riches are, there appears to be two Bathing Rooms, and the whole Piece being of the Ionic Order, is in all Likelihood no inelegant Entertainment to the curious Traveller.

PLATE LIII. Is the Fountain of the Gallery in the Gardens of *Belvidere*, in the Palace of the *Vatican*, belonging to the Great Pontiff at *Rome*, the Architecture of *Carlo Maderno*. As for the farther Description or Account of it, with the Judgment which is proper to be pass'd on a Design of this Nature, I must leave it to the Decision of those who have seen, and consequently understand it better than I do.

PLATE LIV. Is, I humbly conceive, compos'd of as fine a View to a Grove of Cypresses, as is to be seen in any of the Gardens of *Italy*: But what makes it the most remarkable, is, the two large Moles of Stone, on the Right and Left of the middle Walk, through the Middle of which, a large Stream of Water spouts up into the Air, and falls back again over the rude Stones in various Forms. This Imitation of Nature, so peculiar to the Genius of *Italy*, is so very remarkable, that I can't but with great Humility offer it as a Specimen to the Curious in *Great Britain*.

THIS Fountain is situate in the Gardens of the Family *d'Esse* at *Tivoli*.

PLATE LV. Is a Fountain, or rather Cascade, or Theatre of Water, which is on the Top of the Hill near the *Franciscan Nunnery*, in the *Villa Aldobrandini*, or *Belvidere* Gardens of *Frescati*, which is convey'd to that Place by a Current of Water six Miles in Length.

THIS Piece of Water, the Fall of which is at least 8 or 10 Foot high, together with two other Arches and Masques, appears to be amongst the Number of the finest Water-Works of the *Frescati*,
and

and from which a noble Lord in *Hampshire* (I mean my Lord *Ly-mington*) seems to take the Model of one he has at *Down-Husband*, near *Whitchurch*, in that County.

THAT Variety, as well as Rurality of Trees, which appears in the Print, to be on each Side of the Cascade, must needs make a great Addition to the Nobleness of this Design, in which the Architect has followed one of the best Copies of Nature imaginable.

PLATE LVI. Is a Fountain which on one Side appears to be upon the Flat in the *Belvidere* Gardens at *Frescati*, which coming out of the Side of the Hill, and set in rural Works, and Rocks of Stone, must have all the good Effects that an *Italian* Genius can produce.

THE Branches of Water under the great Arch which is in the Middle, and which falls very precipitately down, together with the *Tritons* and great Masques of Water which are on each Side, through which the Water runs with great Violence, seems much to excel all the Finery and Gaiety of the *French* Designs, and the Borders of the Fountain being all of Rustick Work, appears to be no inconsiderable Addition to the Rurality of this Design.

PLATE LVII. Which is call'd the Fountain of the *Dove* in the *Pamphilian* Palace at *Rome*, may (I humbly believe) be well plac'd amongst the best Pieces of Art (as being the most agreeable to Nature) of any that are found amongst the *Roman* Works.

THE Structure of the whole Fountain appears to be of rough unpolish'd Stones, chain'd or cramp'd together with Iron, in a rude, rustick Manner; yet so as that some Footsteps of Architecture are plainly discoverable: Of that Number is the Impost at the springing of the Arches, and the geometrical Turn of the Arches.

I TAKE it to be a great Pity that there are no more Books extant, and that so many Noblemen and Gentlemen that travel into those Parts have brought no better Account as to the Extent and Proportion of these Structures; however, this Effect I hope these Endeavours of mine will have, that upon a View of these cheap and useful Beauties, Rural Architecture will get Footing in these Kingdoms, as well as other Countries less able to perform them than we are.

PLATE LVIII. Is the Fountain of the *Sybils*, commonly call'd the *Great Fountain*, where the Statues of the *Sybils* are in the Niches, on the Side of the Walk of the little Fountains, in the Gardens of the

the *d'Este* Family at *Tivoli*, which in Respect to the Beauty and Justness of the Architecture, as well as the fine Sheet of Water it makes through a Grove of large Trees, may be justly plac'd amongst the most curious Pieces of Art in the *Italian* Gardens.

AND here indeed is again visible, how great a Pity it is, that we have not the exact Dimensions of this and other Fountain-Works delineated and brought over for our Imitation: Buildings of this Kind in Stone, would be indeed some, (though not a very great) Expence, but as we have Plenty of Hedge-Yews ready grown, it would be very easy to imitate such a Design as this is, in a few Years.

PLATE LIX. ONE of the last Plates I shall produce, and which will in a very handsome manner compleat this Collection, is a View of the Cascade under the Organ, in the Plan of the Gardens of *d'Este* at *Tivoli*, in which may be seen all that can possibly be desir'd as beautiful, either in Art or Nature.

I SHALL at present pass by the Account that might be given as to the Pleasure of having Organs play'd by Water falling down from so great a Height, that being already hinted at in the third Book of this Treatise, which relates to Hydraulicks. But whoever views how judiciously and agreeably Art and Nature are here mixt together, and, above all, how much of the latter is here predominant, must confess that this is the most surprizing of any of the Water-Works of *Italy* yet produc'd.

THIS Cascade, or Fall of Water, which can't be less than 50 Foot perpendicular, breaking out as it does from several Parts of the Rock, and dash'd to Pieces in its Cadence, may well be a Surprize to all who earnestly behold it. It is in this that the Water-Works of *Italy* so much exceed those of *France*, even as much as the rude, but masterly Strokes of Nature, exceed the most delicate ones of Art.

PLATE LX. AFTER I have produc'd so many noble Drafts and Descriptions of Water-Works, it may seem a very great Presumption in me to offer one of my own Invention, which must by that great Number of good Designs which go before, be much eclipsed; and all that I can say in Extenuation of the Plate I offer in the last place, is, that it is something like the Water-Works of *Italy*, and that if there is any thing which is valuable in it, it is in a great Measure owing to the Idea's I have form'd from those Works.

ONE of these Kind of Cascades I have sometime since made at *Spy Park* near *Sandy-Lane Wilts*, on the Left Hand of the Road going to the *Bath*, which though done with very poor materials, yet admits

mits of such a Variety, as some good Judges who have been Abroad seem to like, and think equal, at least, to any in the *French Gardens*; the Falls of the Water being over Steps and rough Work of different Kinds and different Heights, of about 30 or 40 Foot Fall.

THE Design here produc'd, was made (though not finish'd) for a young Nobleman of *Hampshire*, some little Time ago deceased, where the Water indeed is not so plenty as it is in the Design mention'd in the last Paragraph; but the Fall of it is shorter, and more precipitate, the Dependance from the Top of the Reservoir to the Bottom being near 50 Foot, and the Turnings and Windings of the Water, with the different Forms of the Cataracts over which it was to fall, would have produc'd (had it been finish'd) all the Variety that such a Place would allow. Nor is this Kind of Work expensive, the Workmanship of the whole rough Stone-Work not coming to above 100 £.

AT the upper End, above the Bason, is the Design of a Cave, or Grotto at the Foot of the Hill, where *Neptune* is plac'd upon his oufy Bed, or Couch, and delivering Water to the Falls below, and what would have been very well, was, that at the Bottom of the said Cascade after the Water had shew'd itself in this sportive manner, it was design'd to supply all the Gardens and House which lie below; and this Supply of Water was to have been from a large Reservoir on one Side of the Hill, collected from Engines, Rains, &c.

The End of the Fourth Book.



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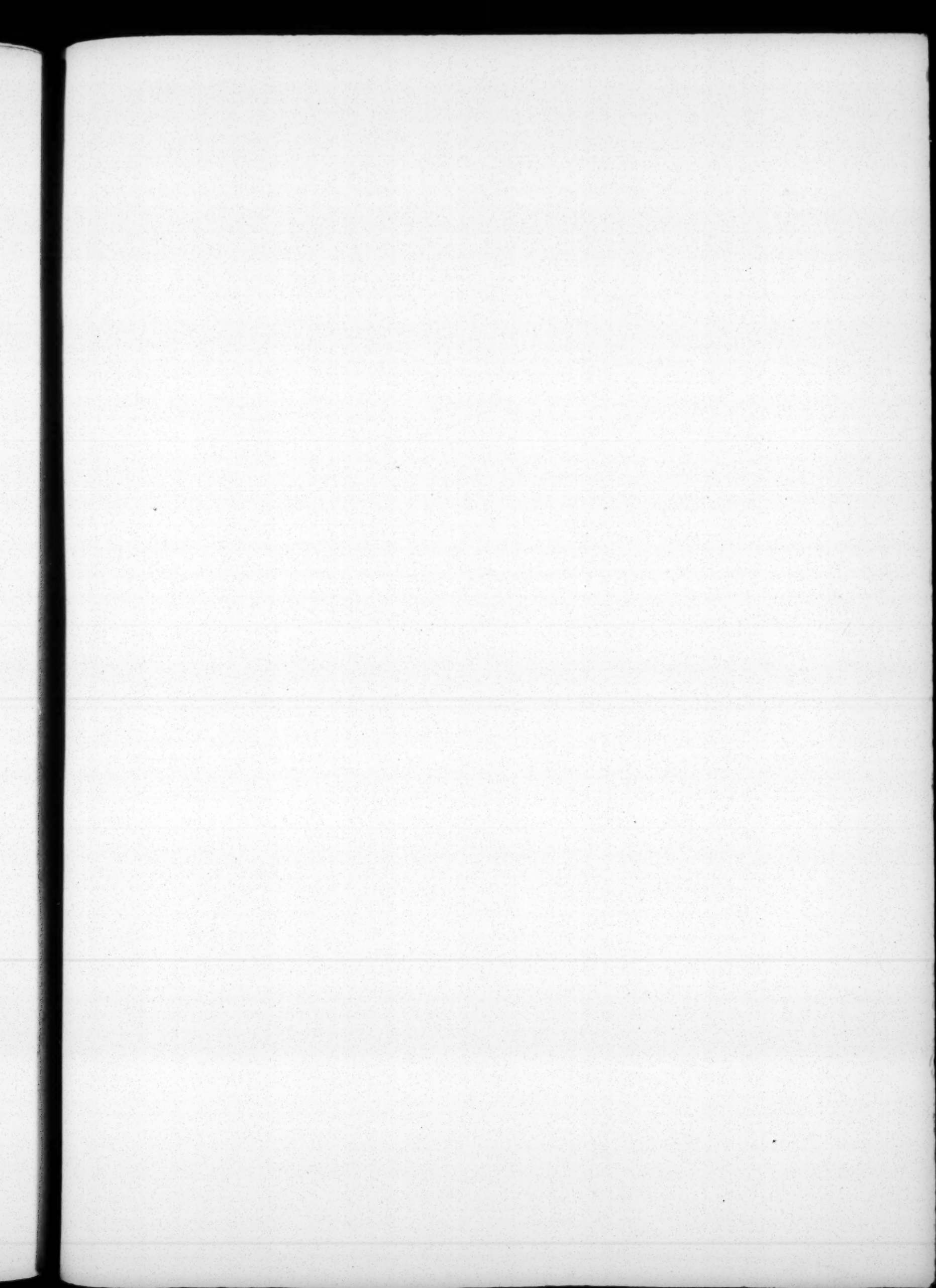
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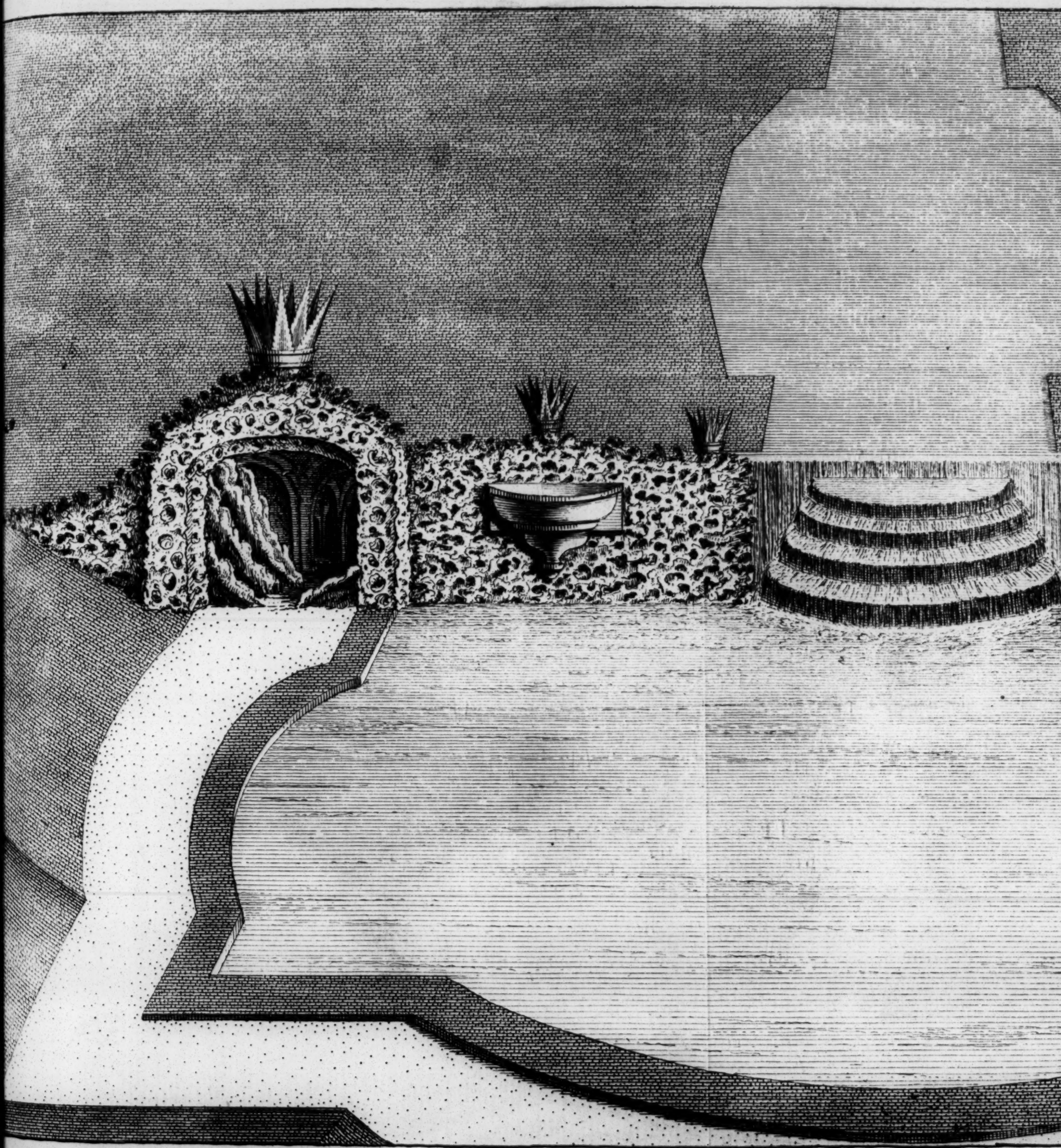
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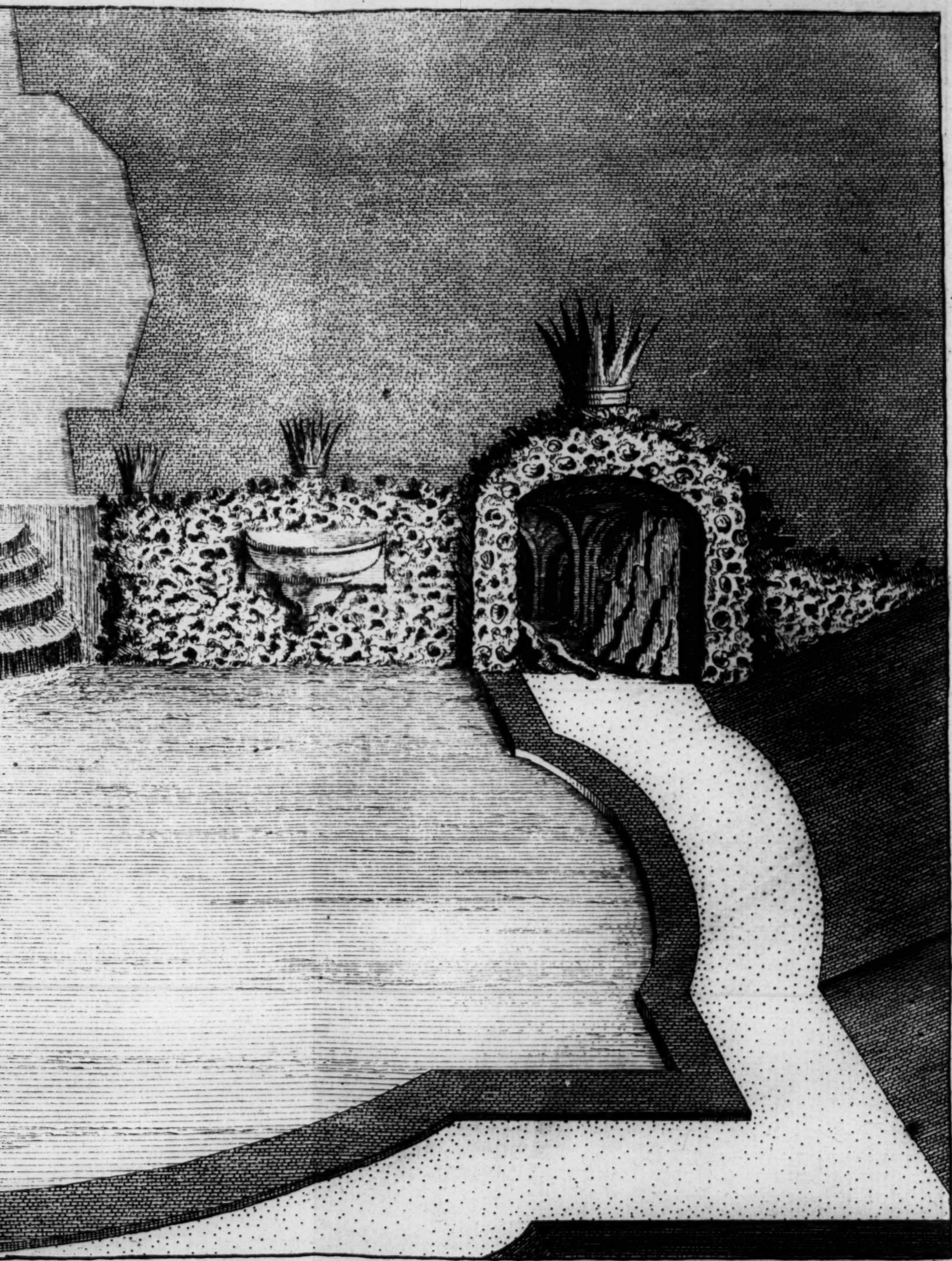
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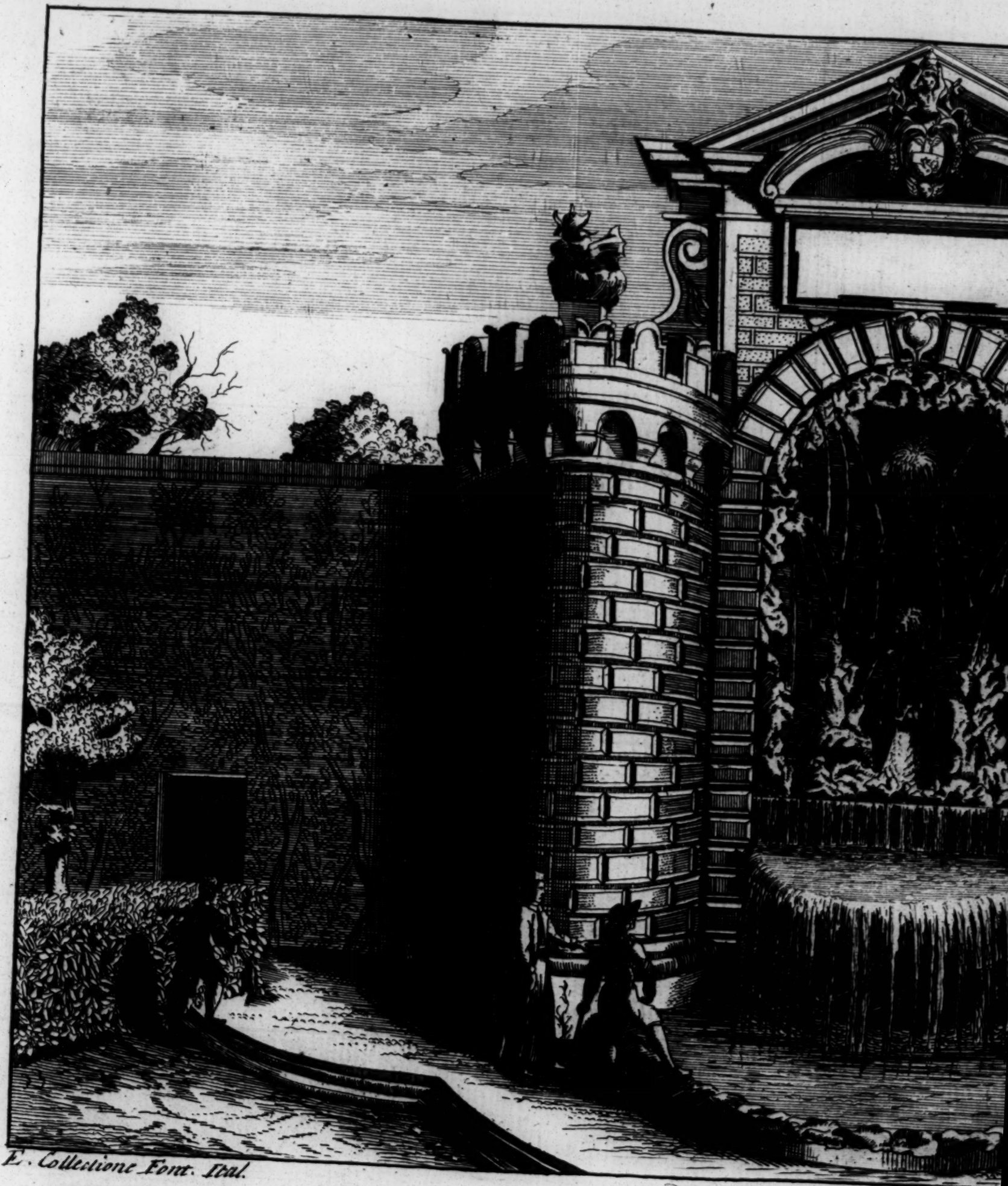




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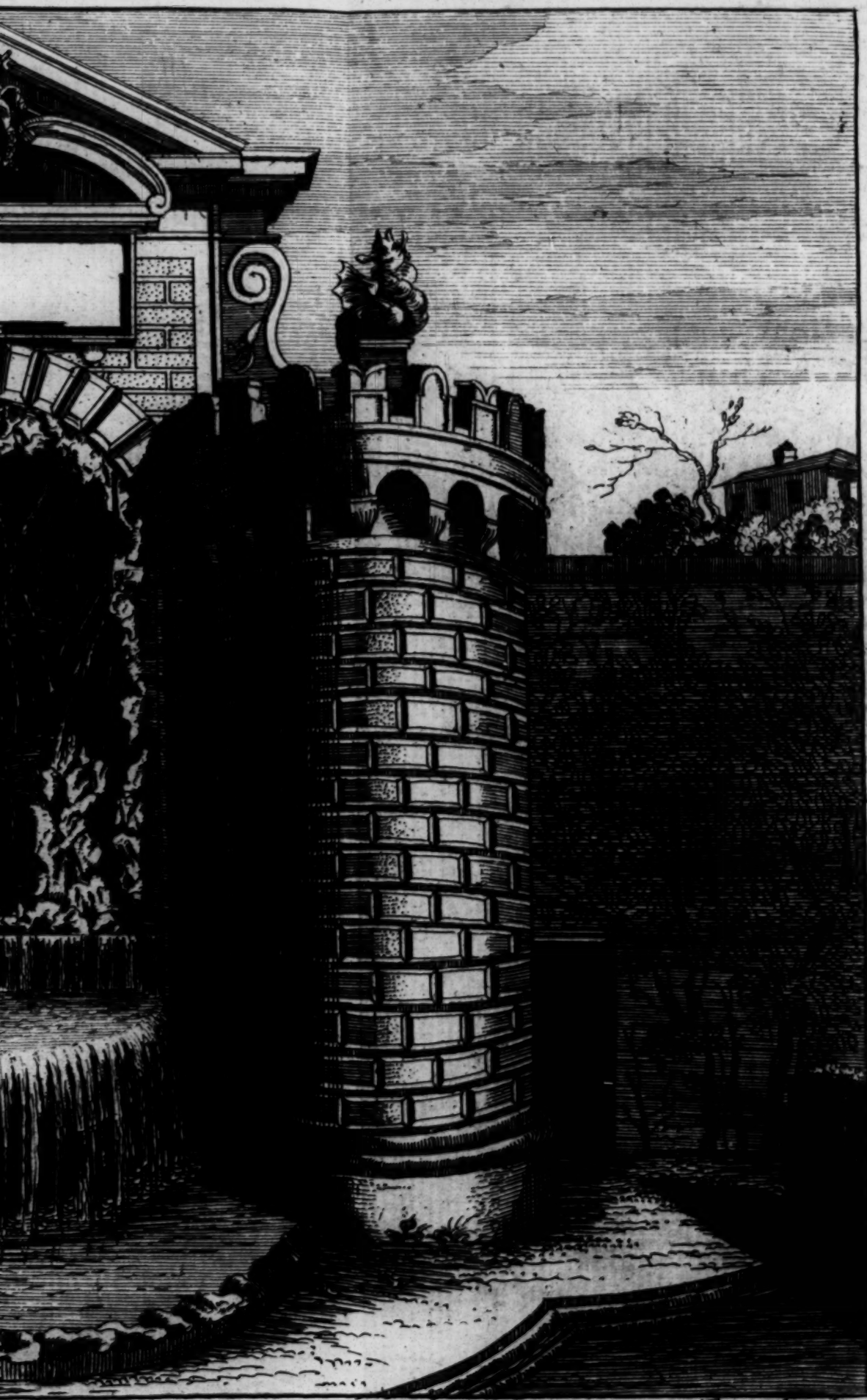


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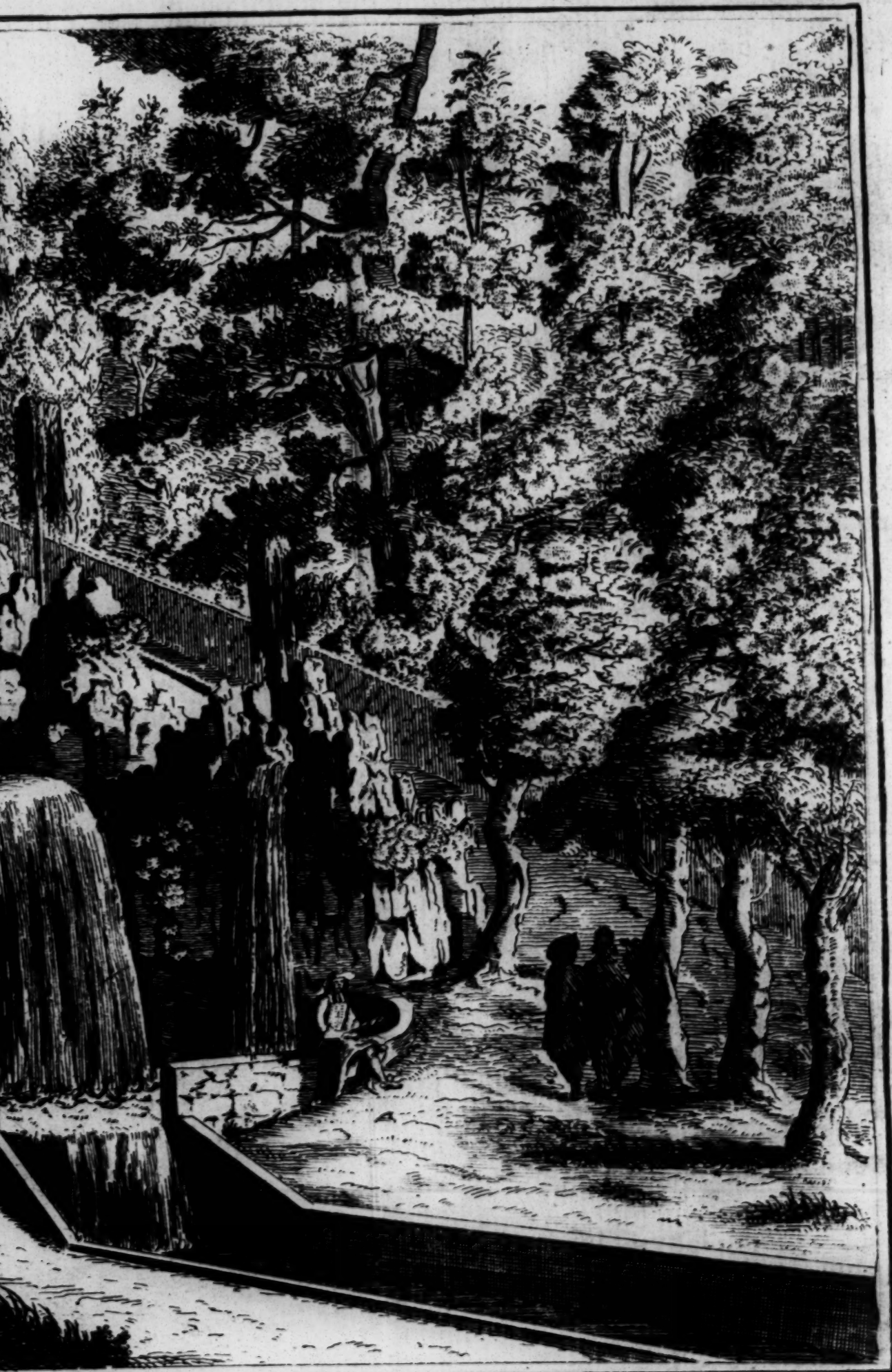


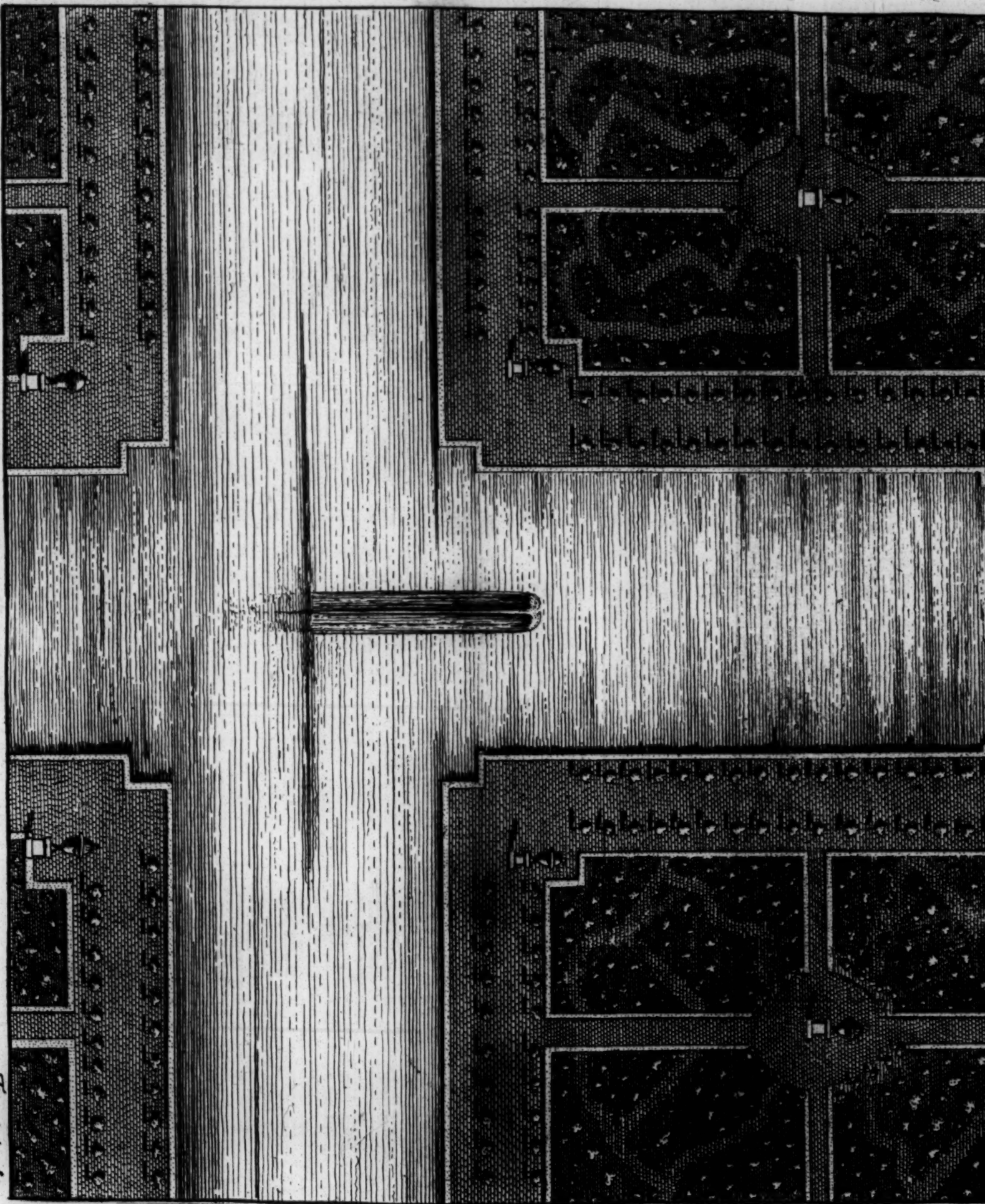
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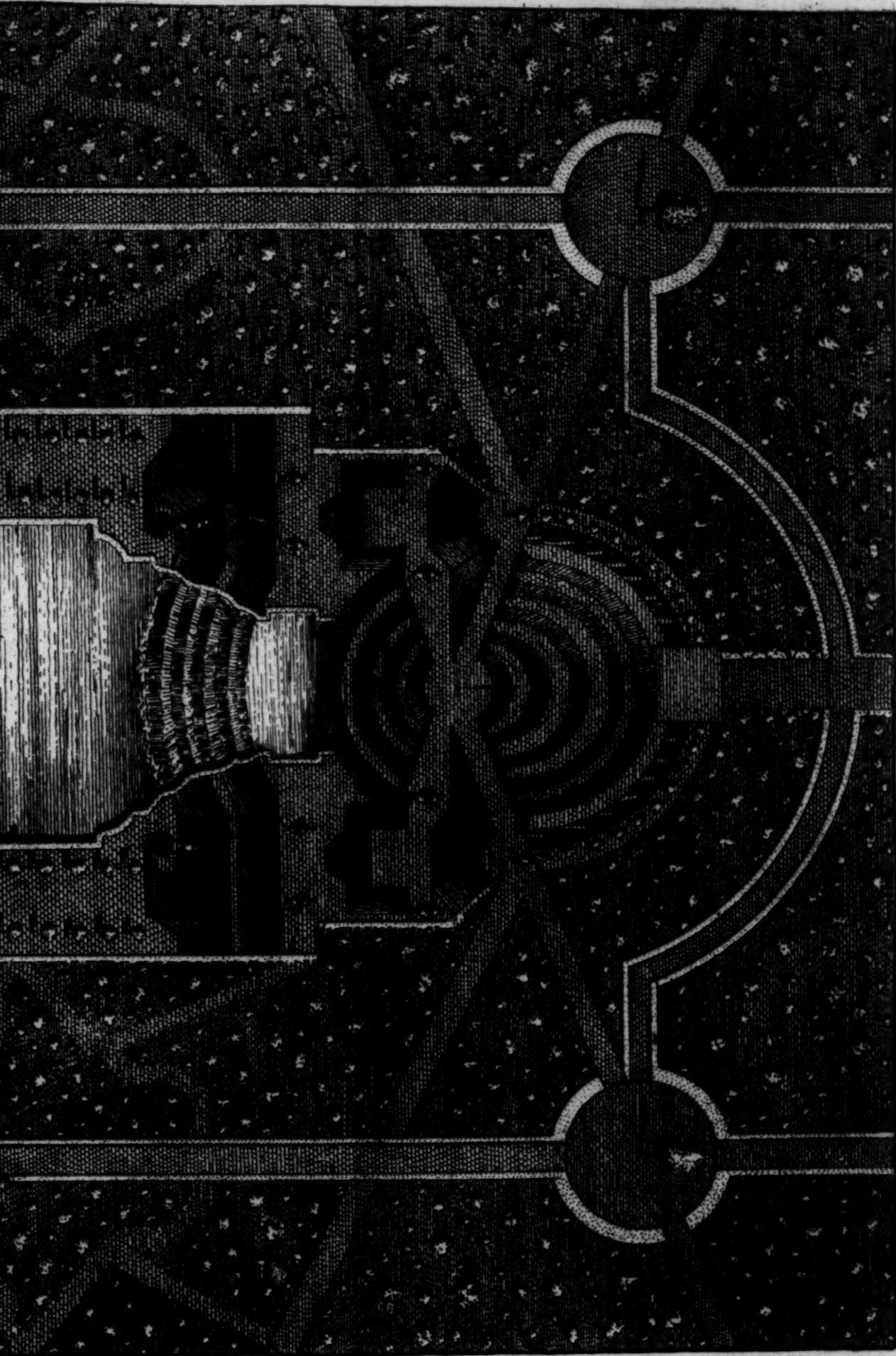




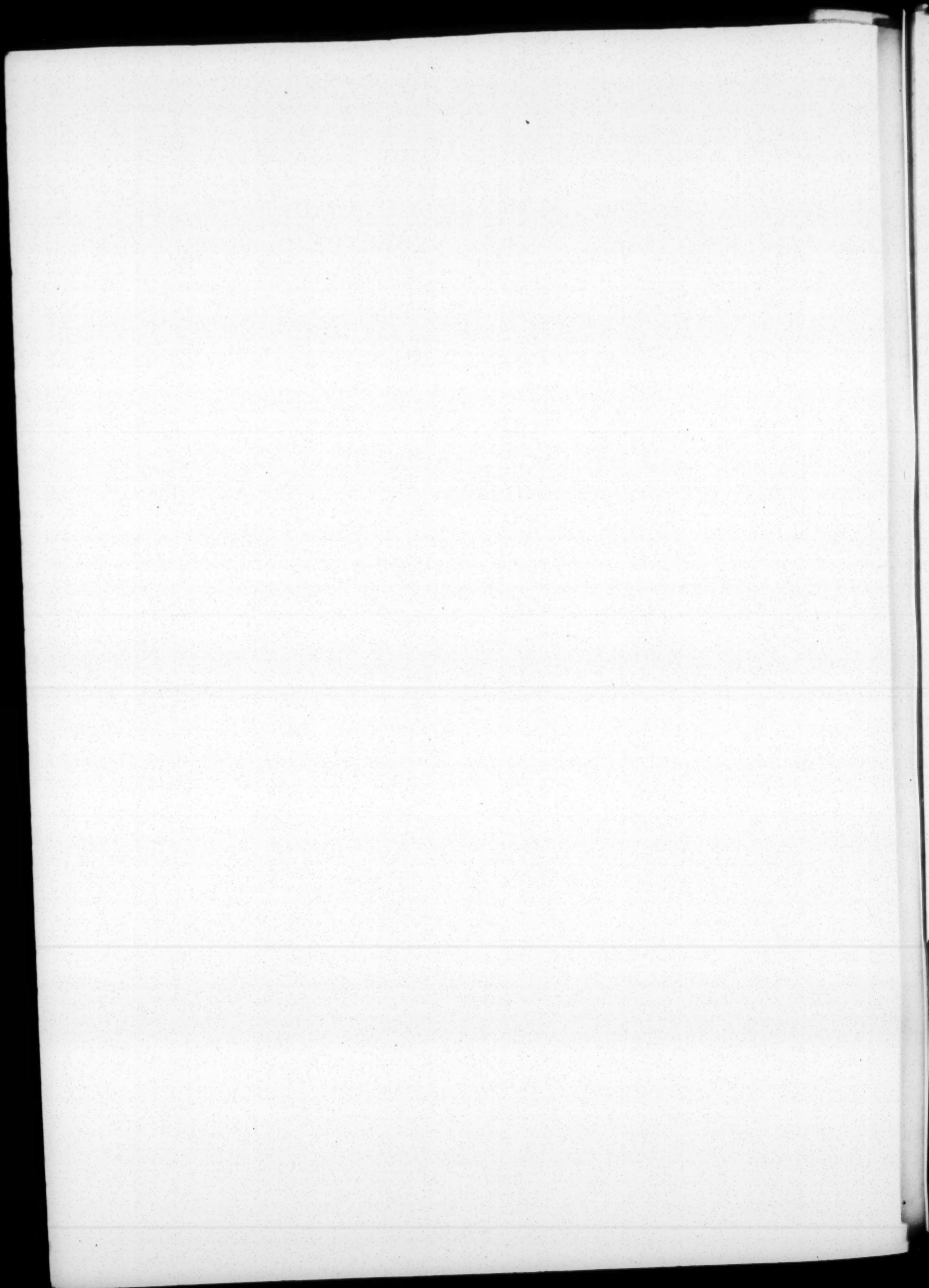
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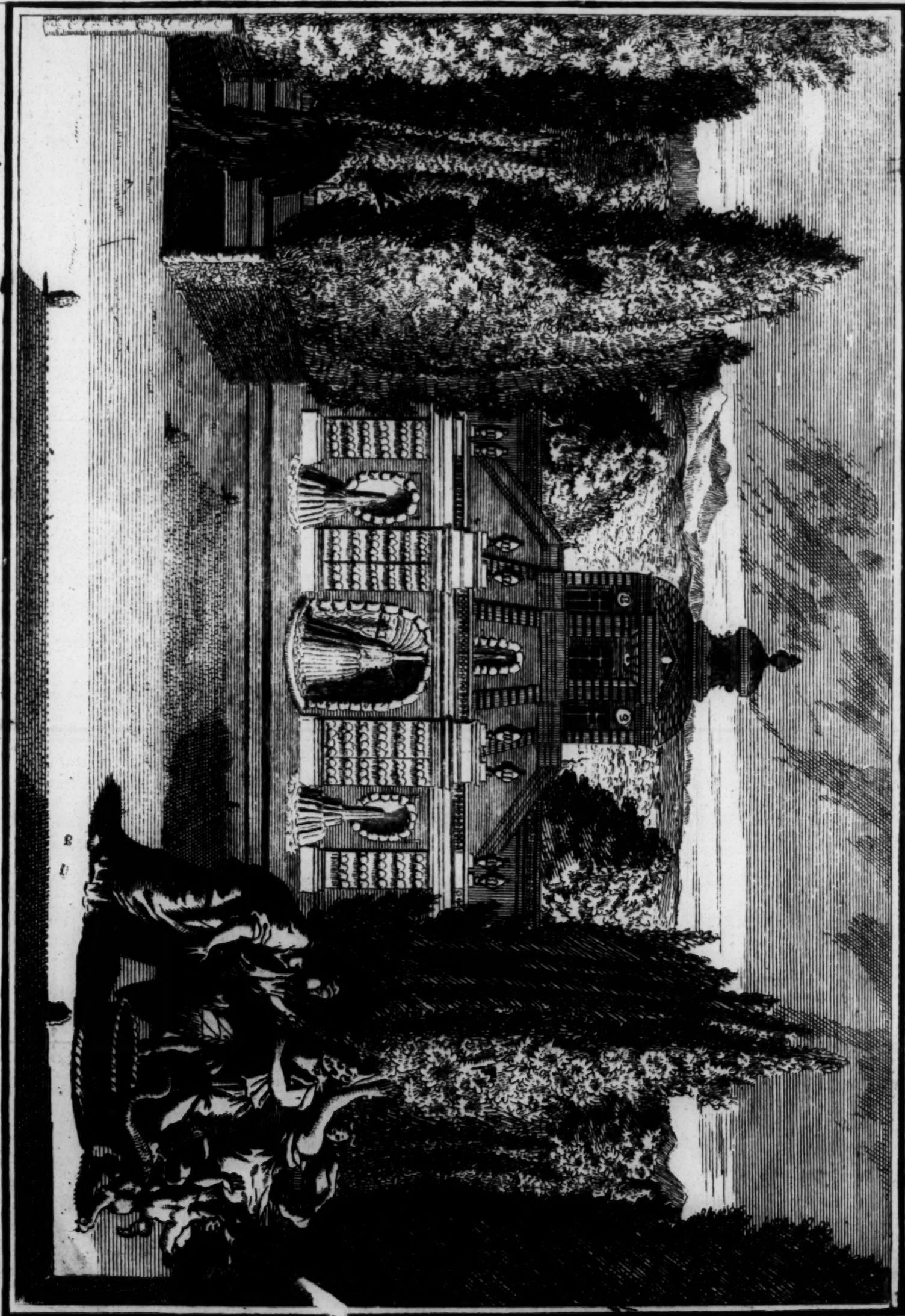
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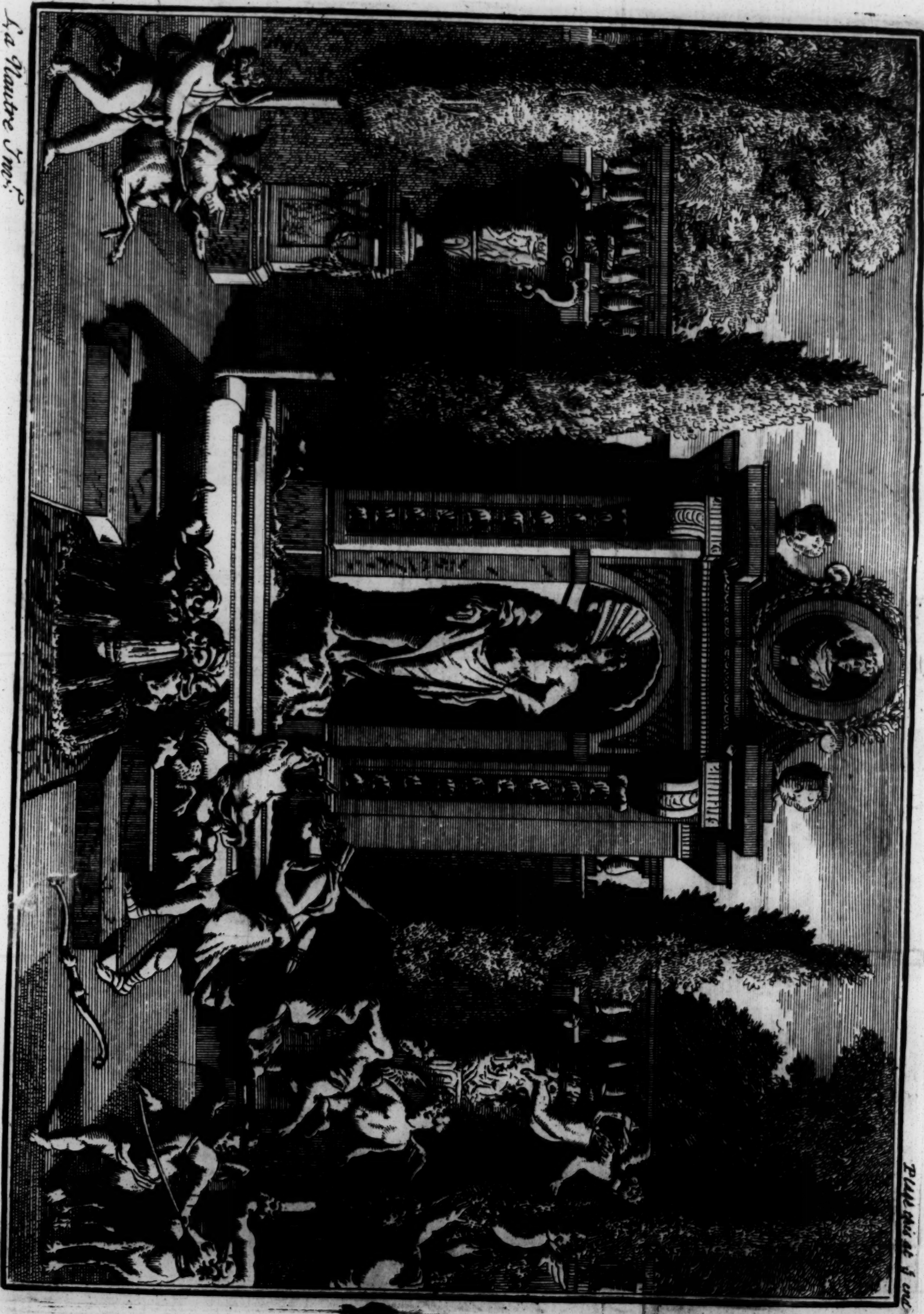


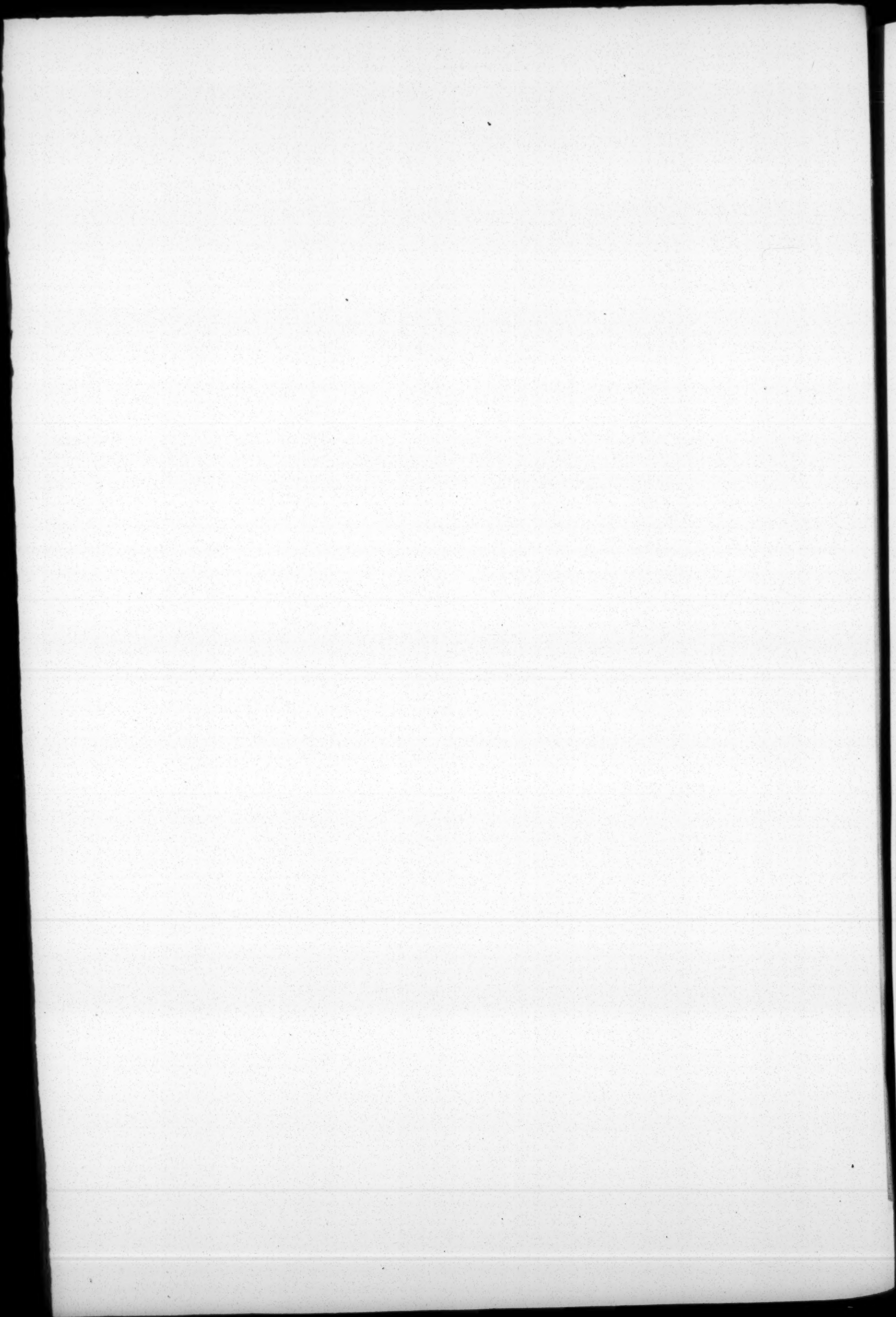


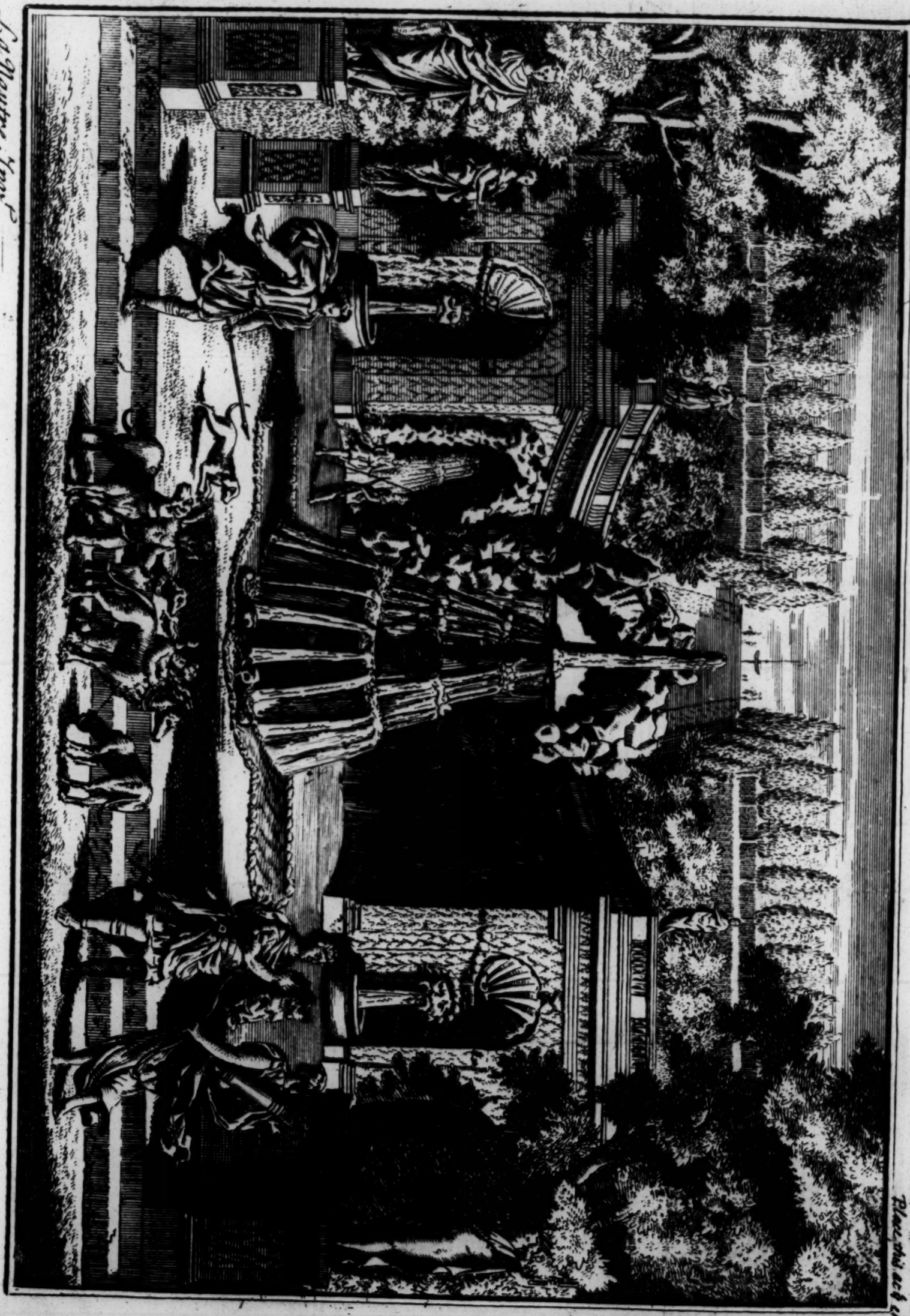
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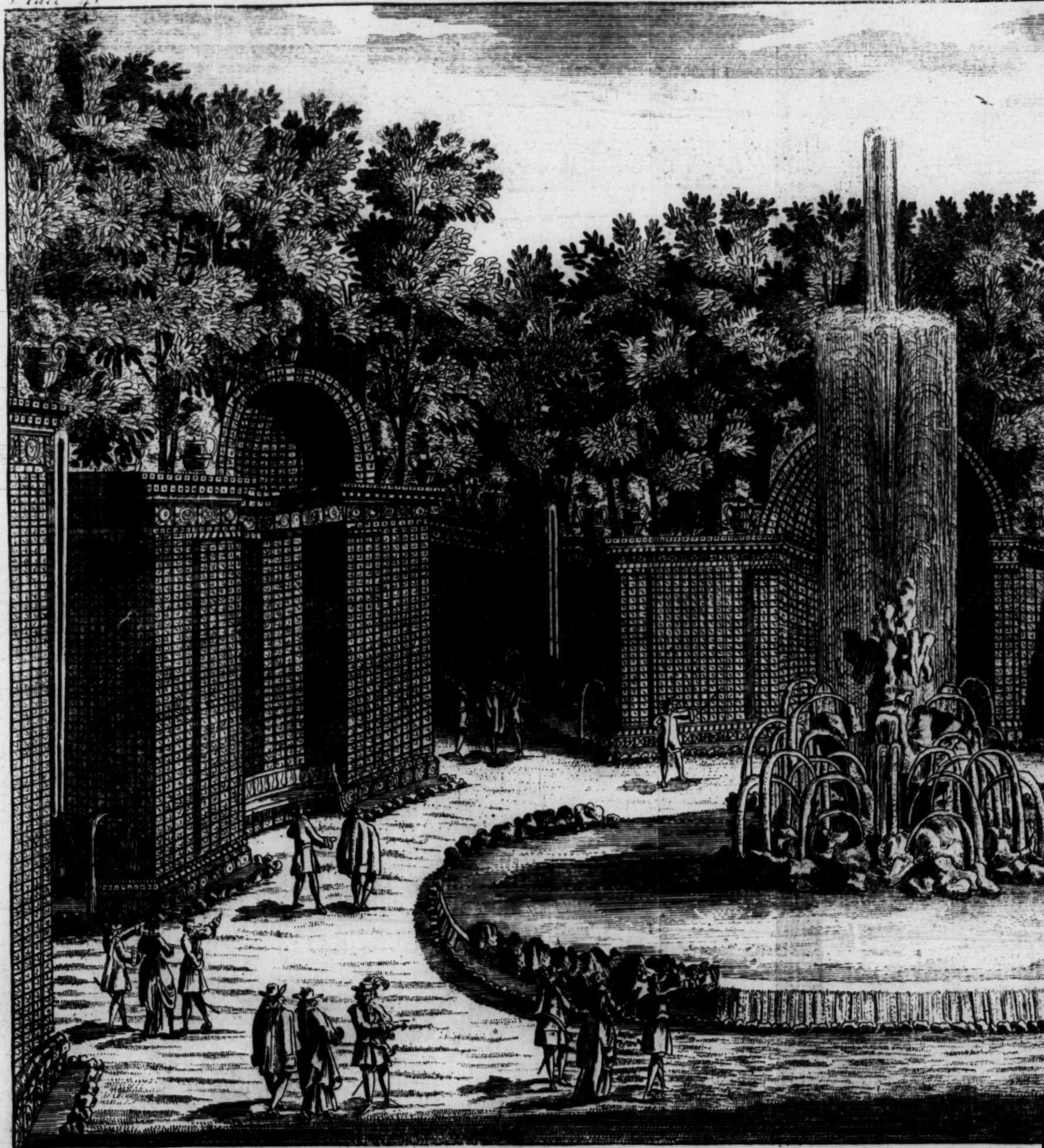
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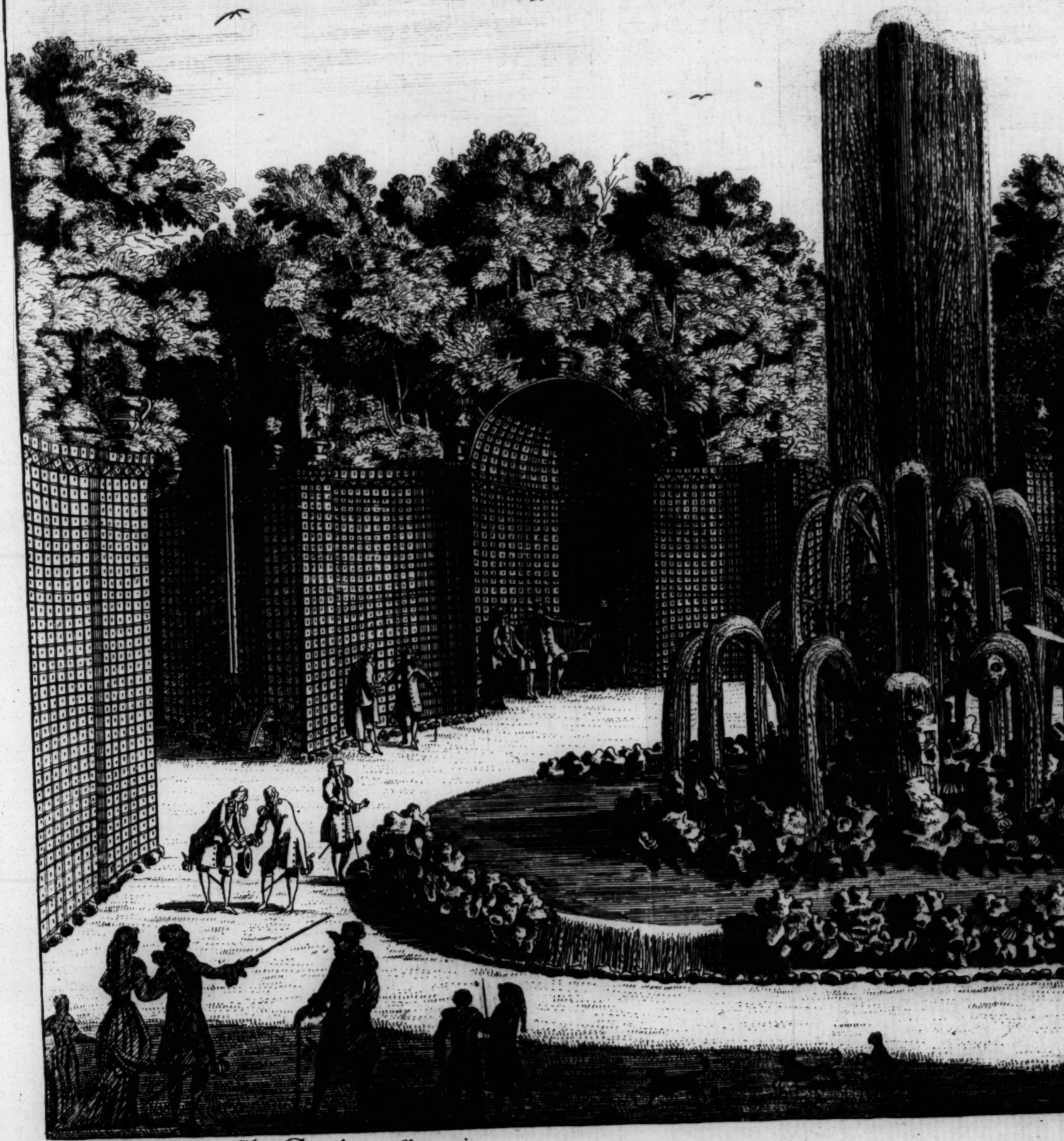


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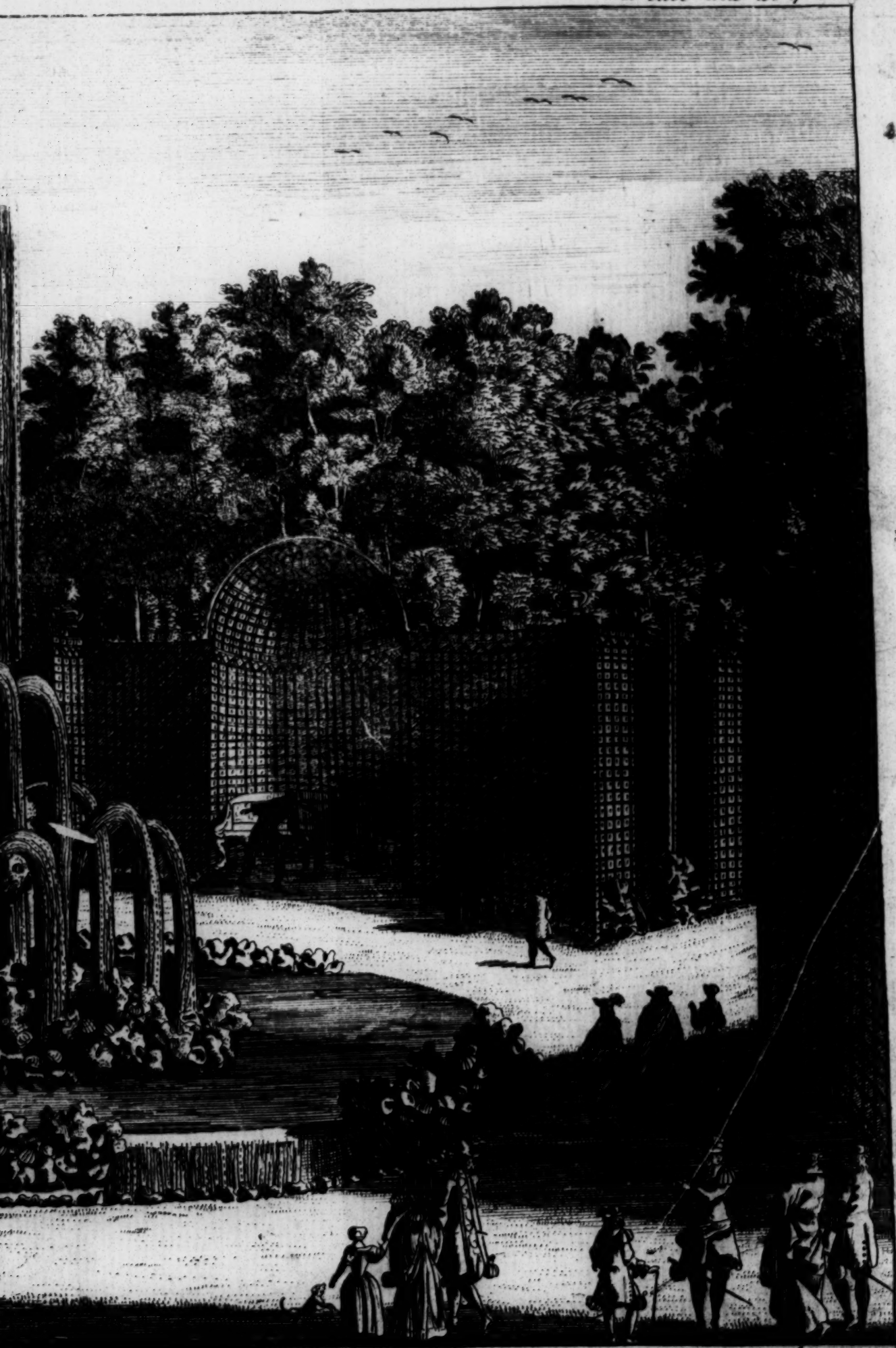


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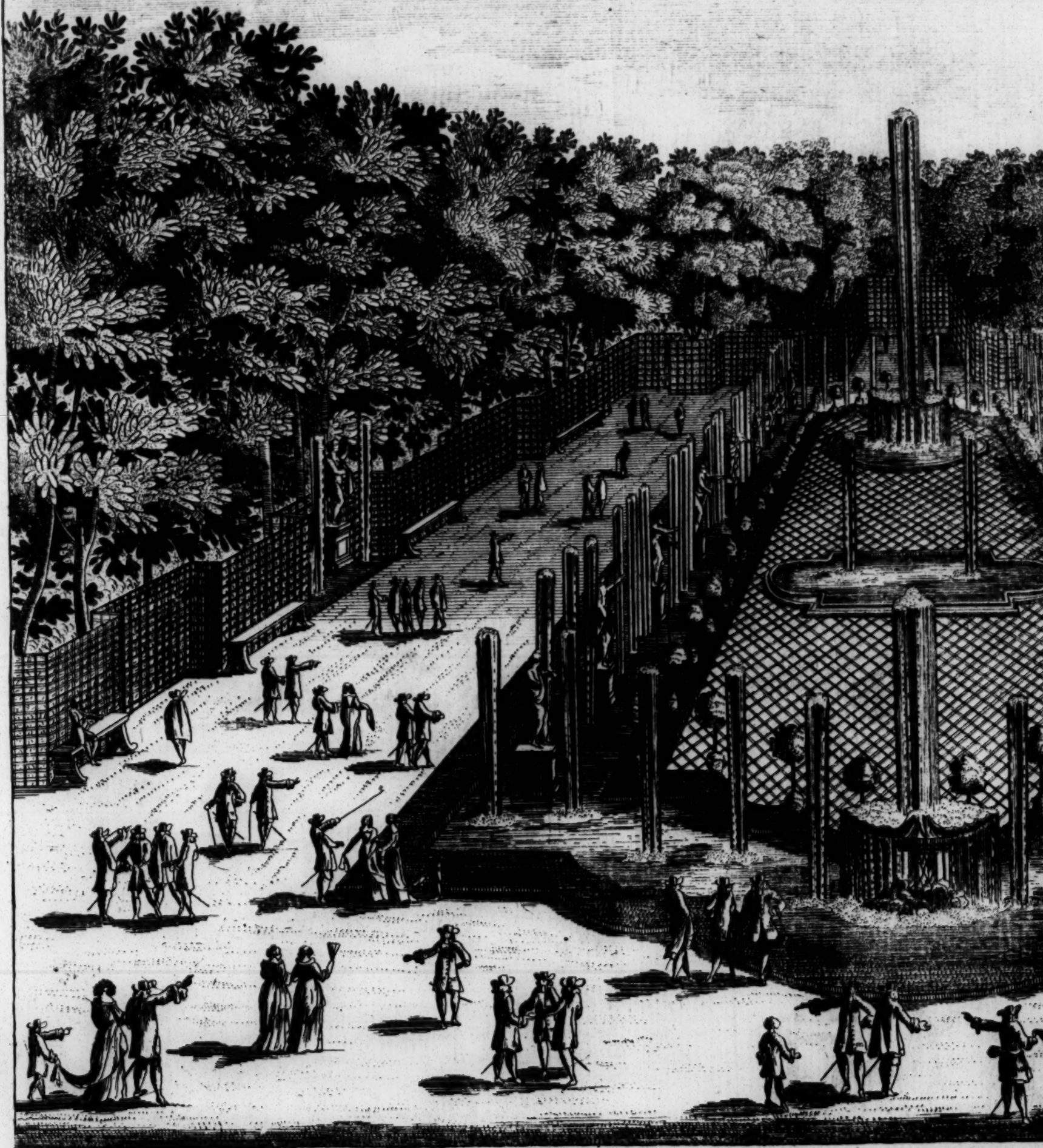


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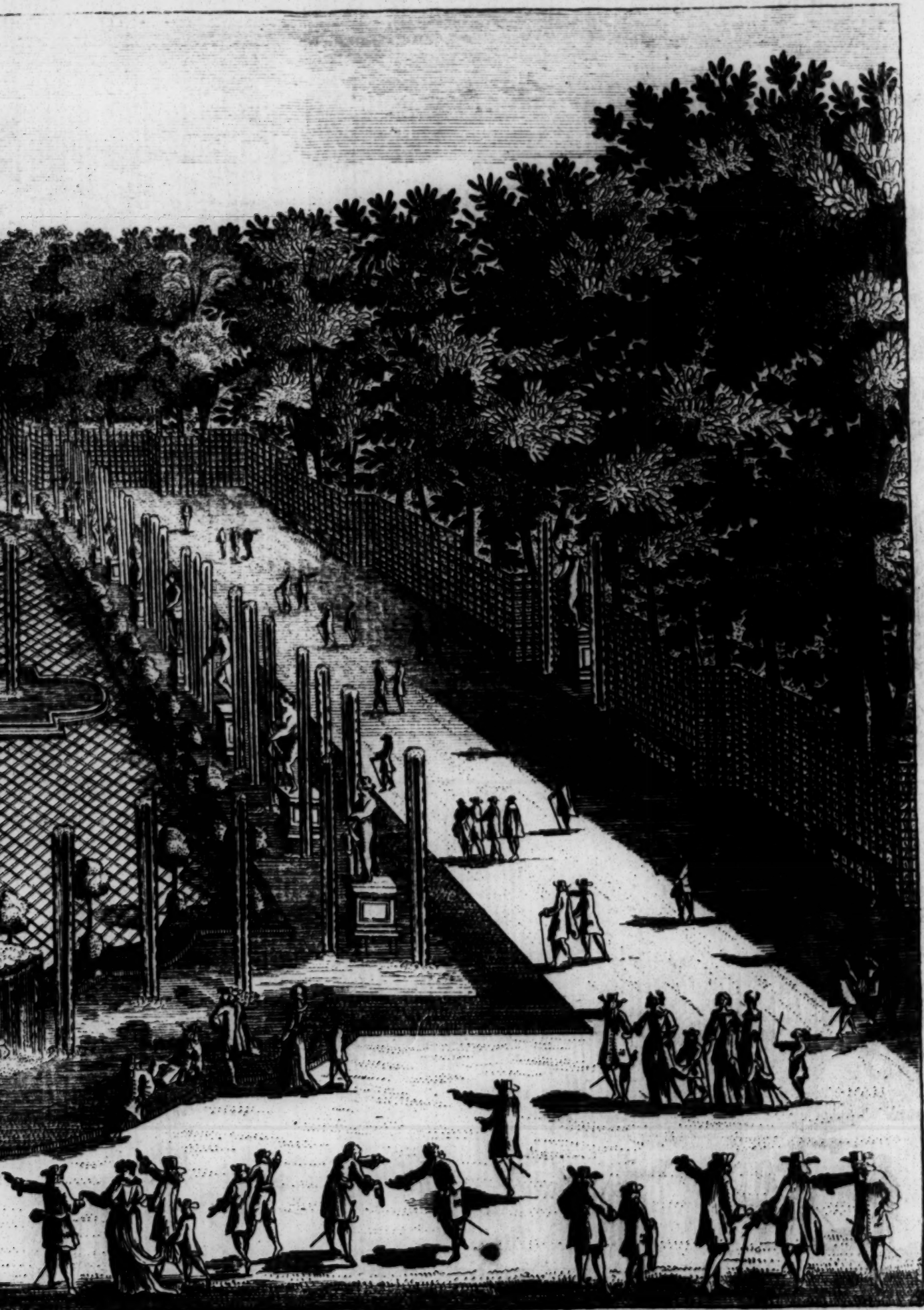


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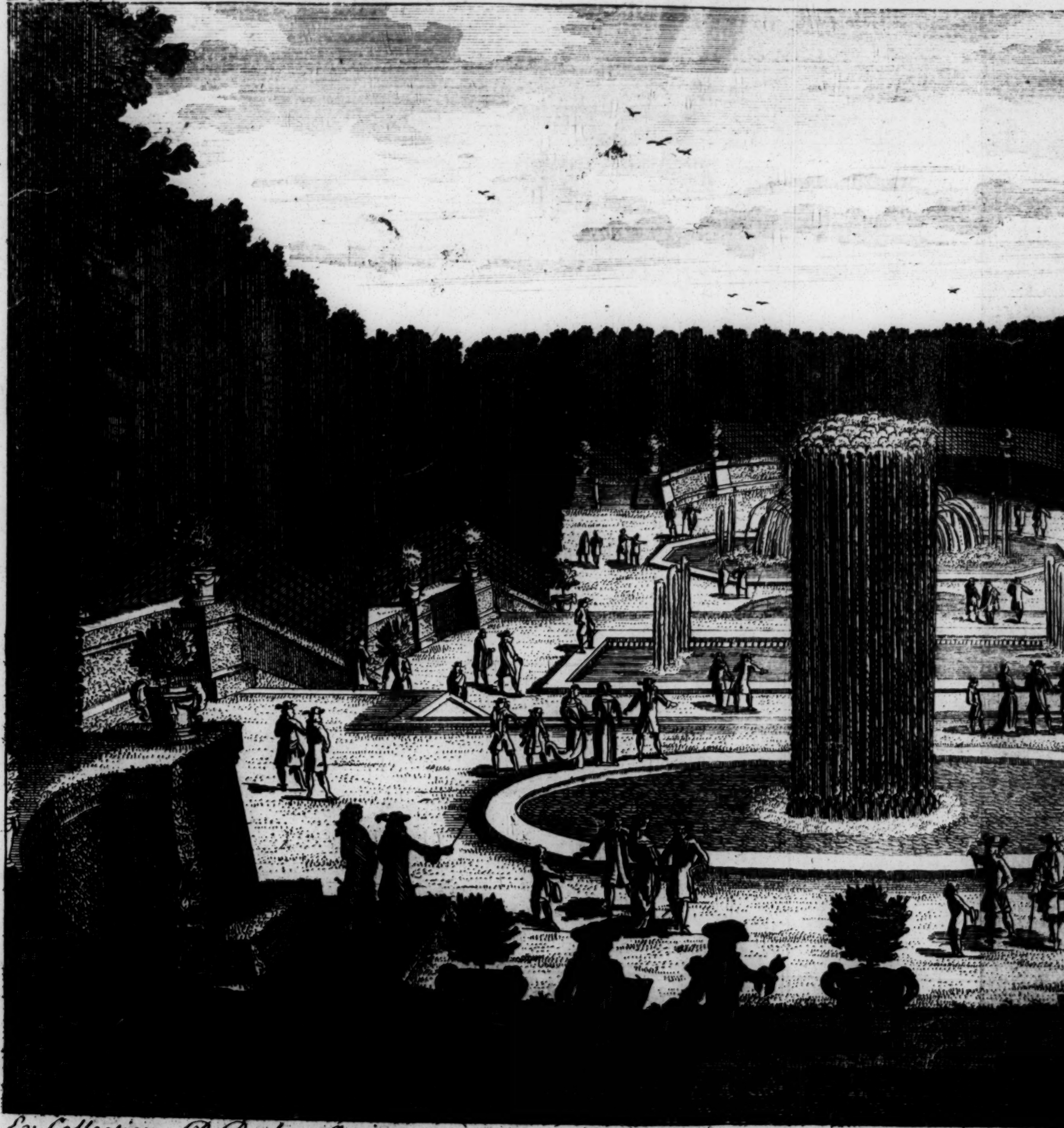


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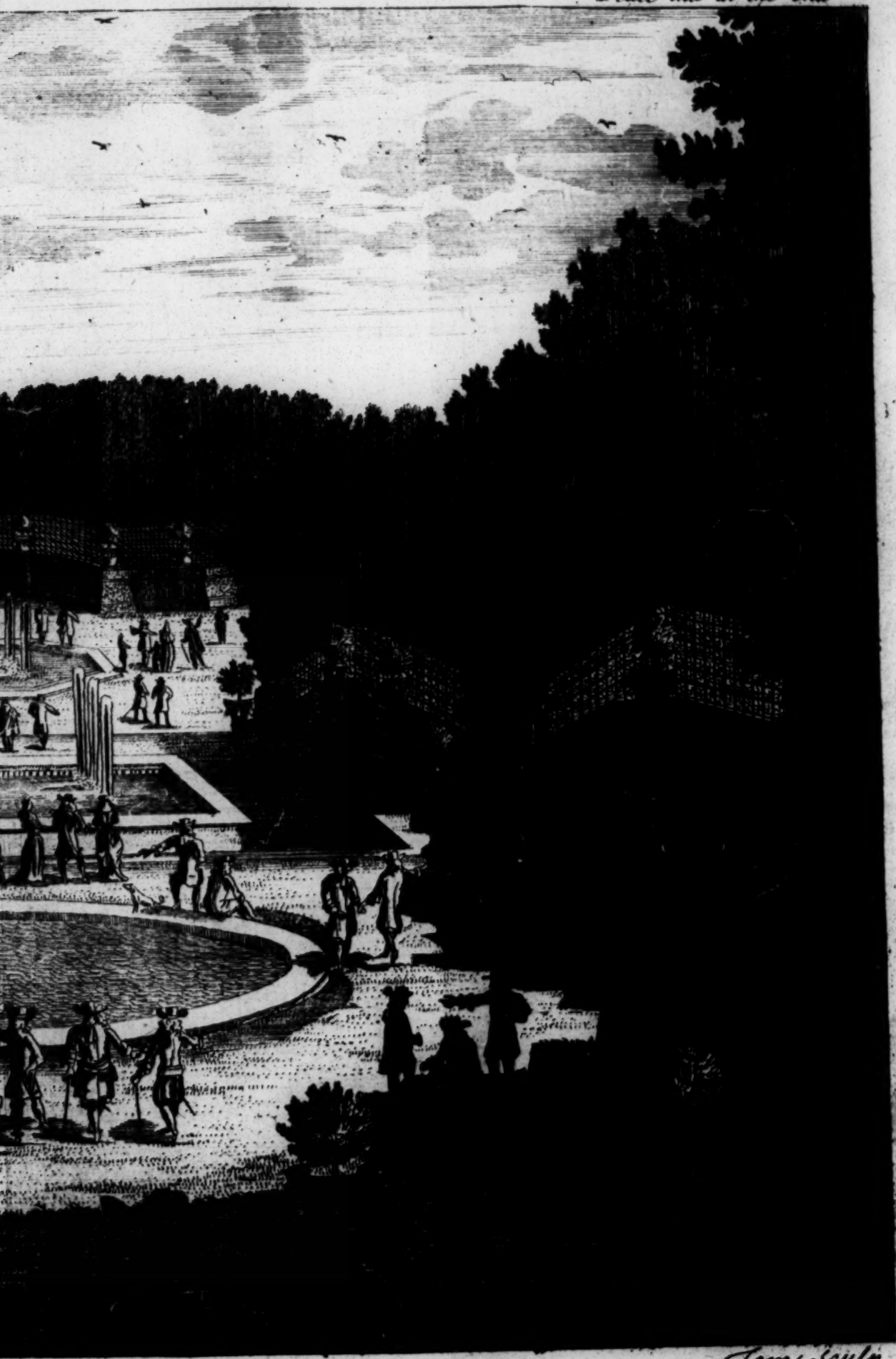


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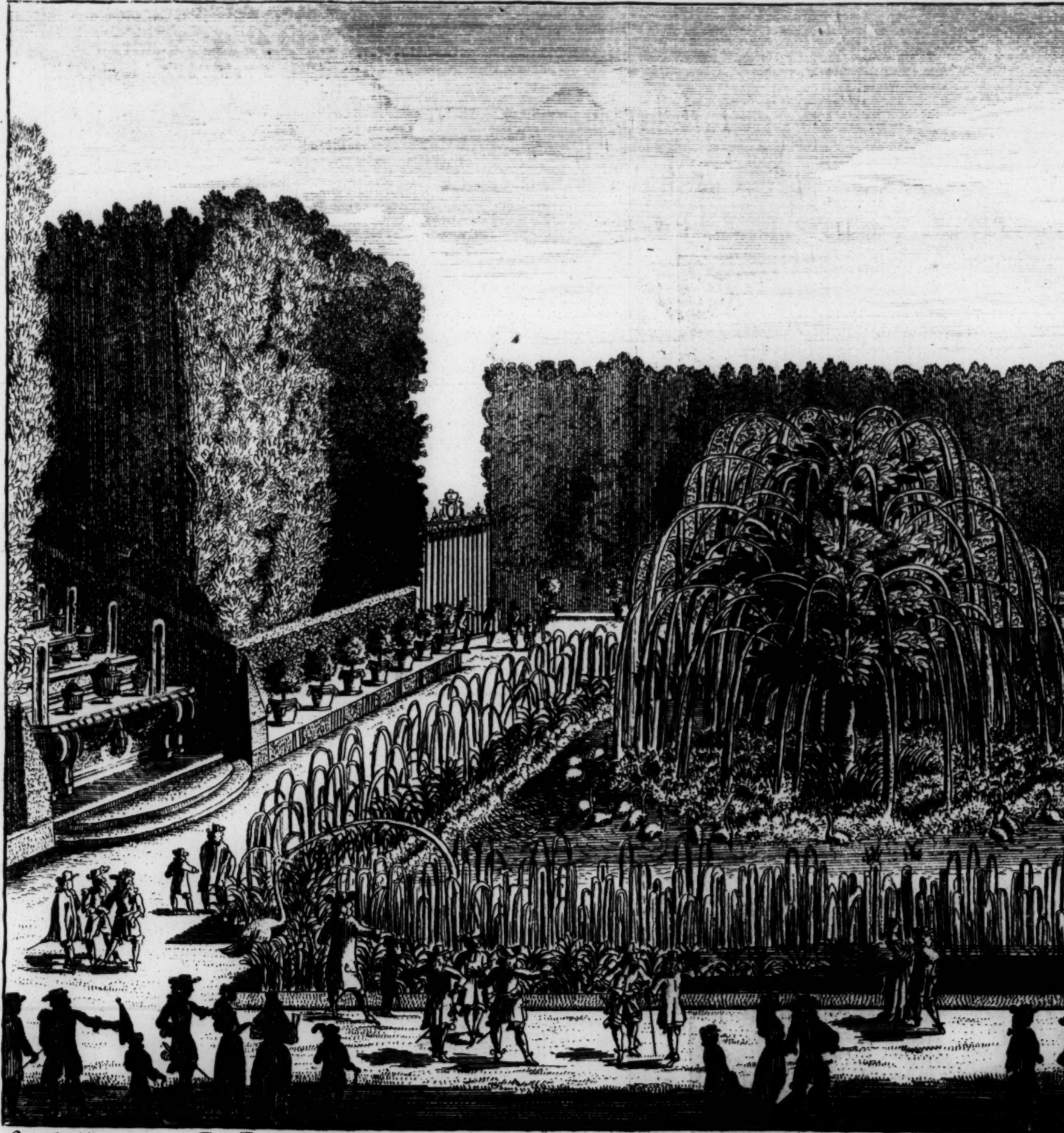


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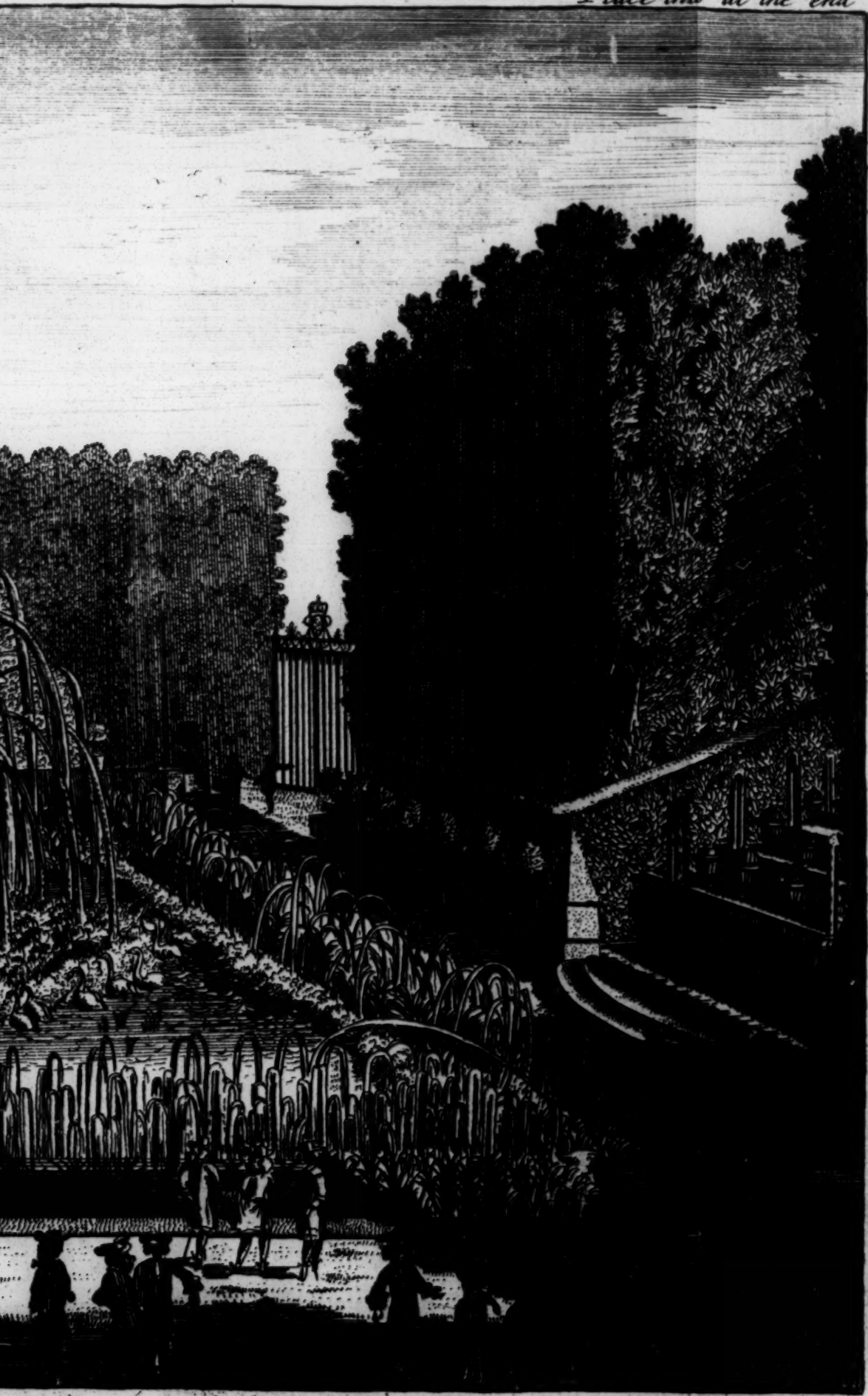


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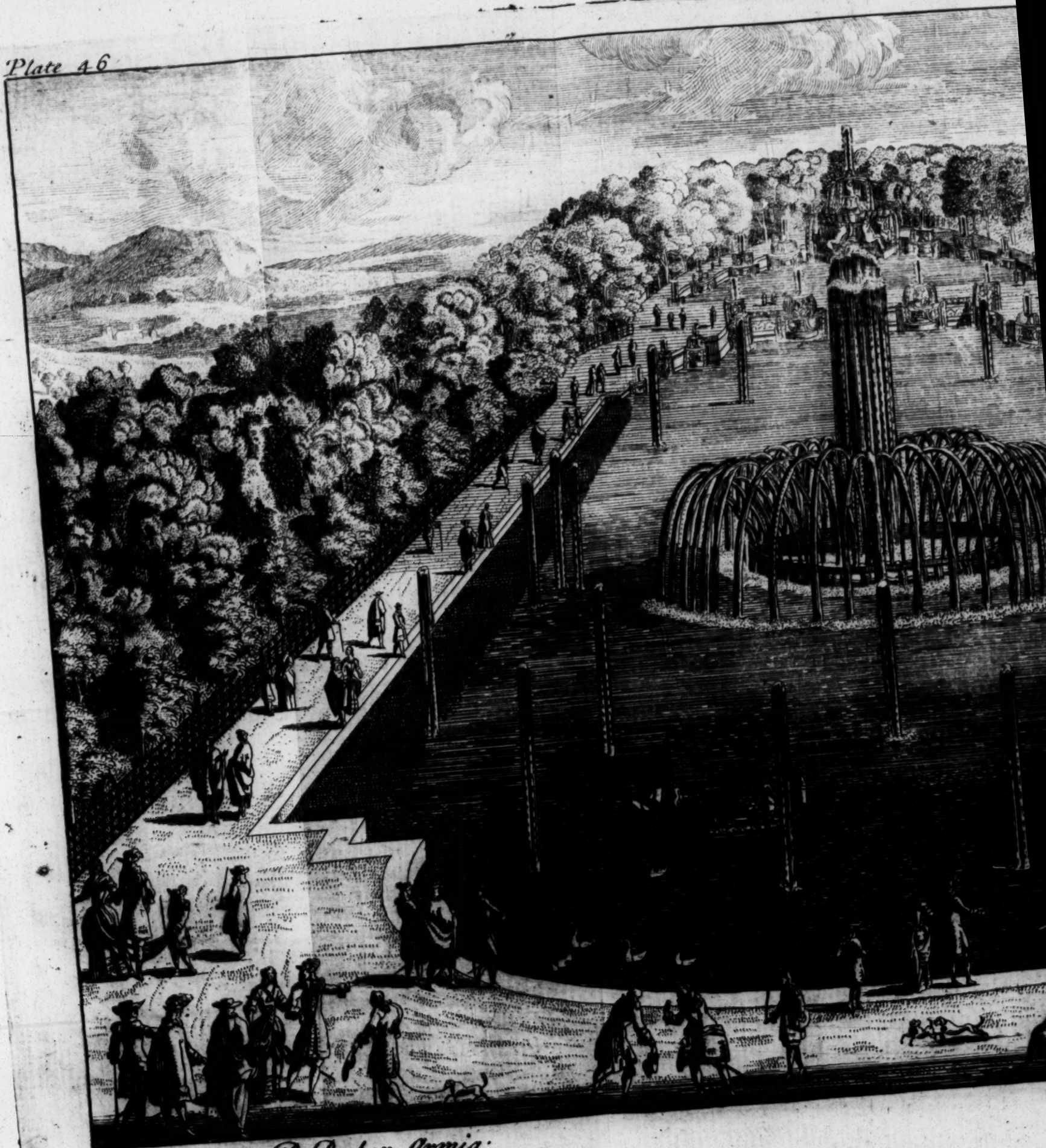


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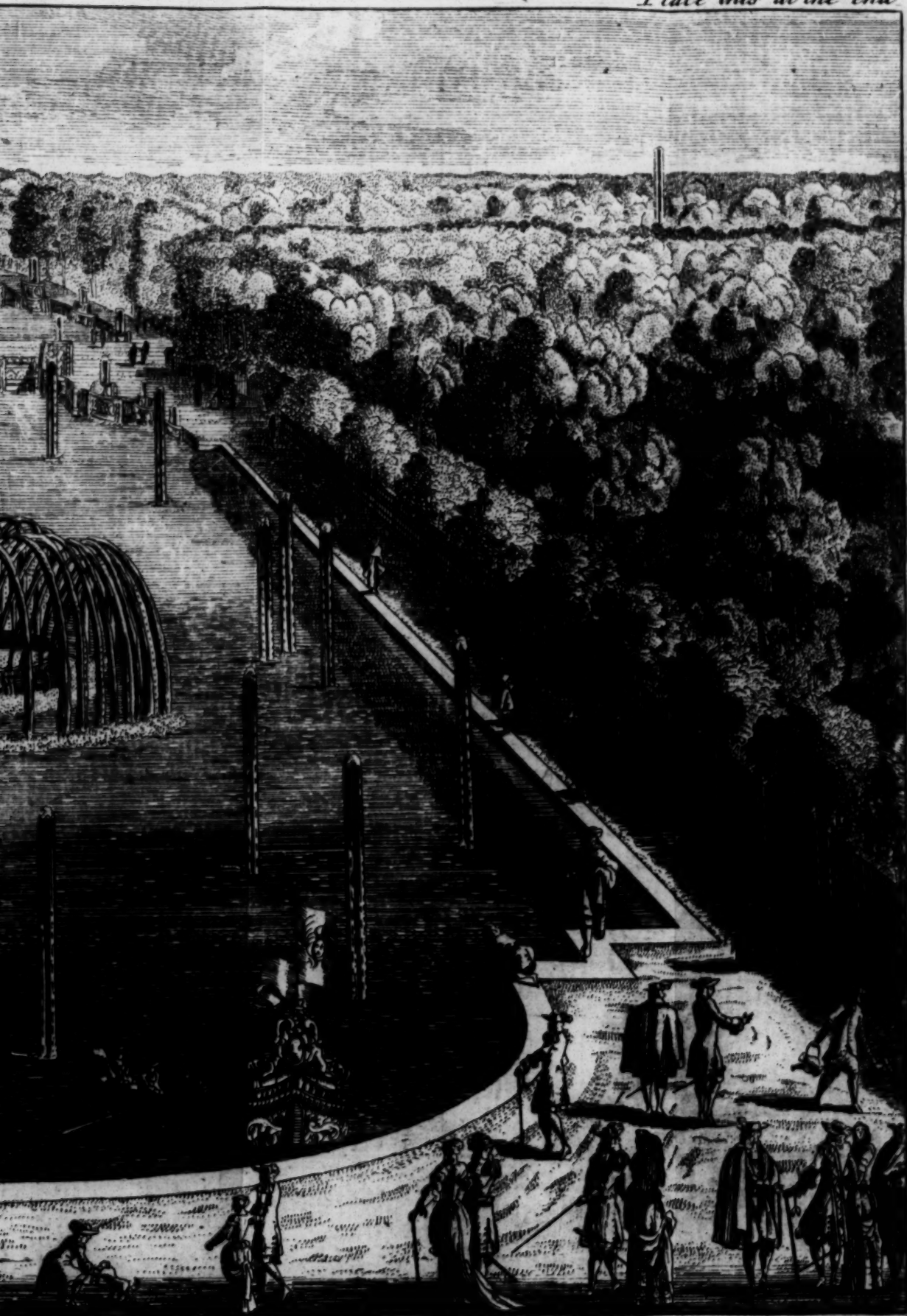


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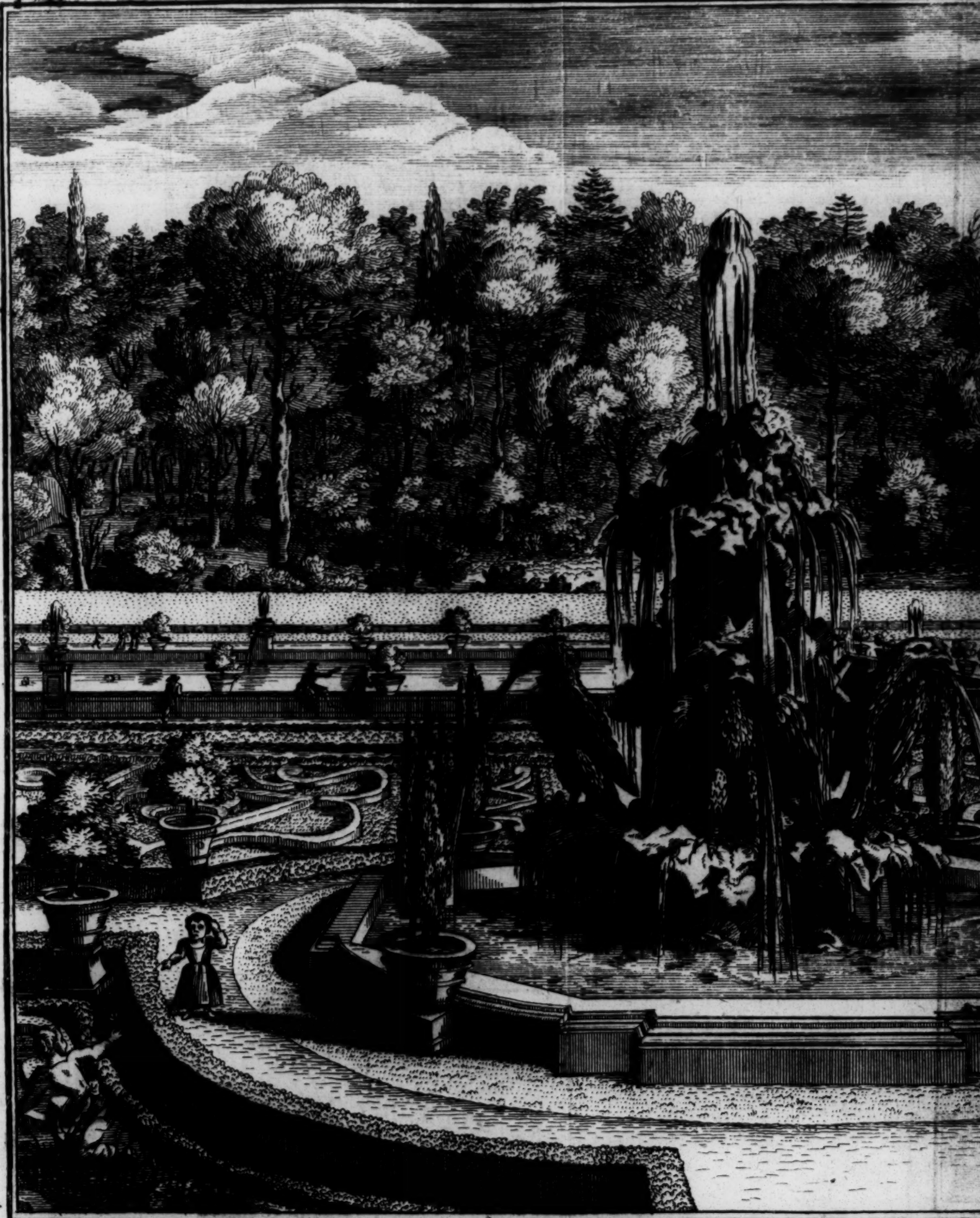


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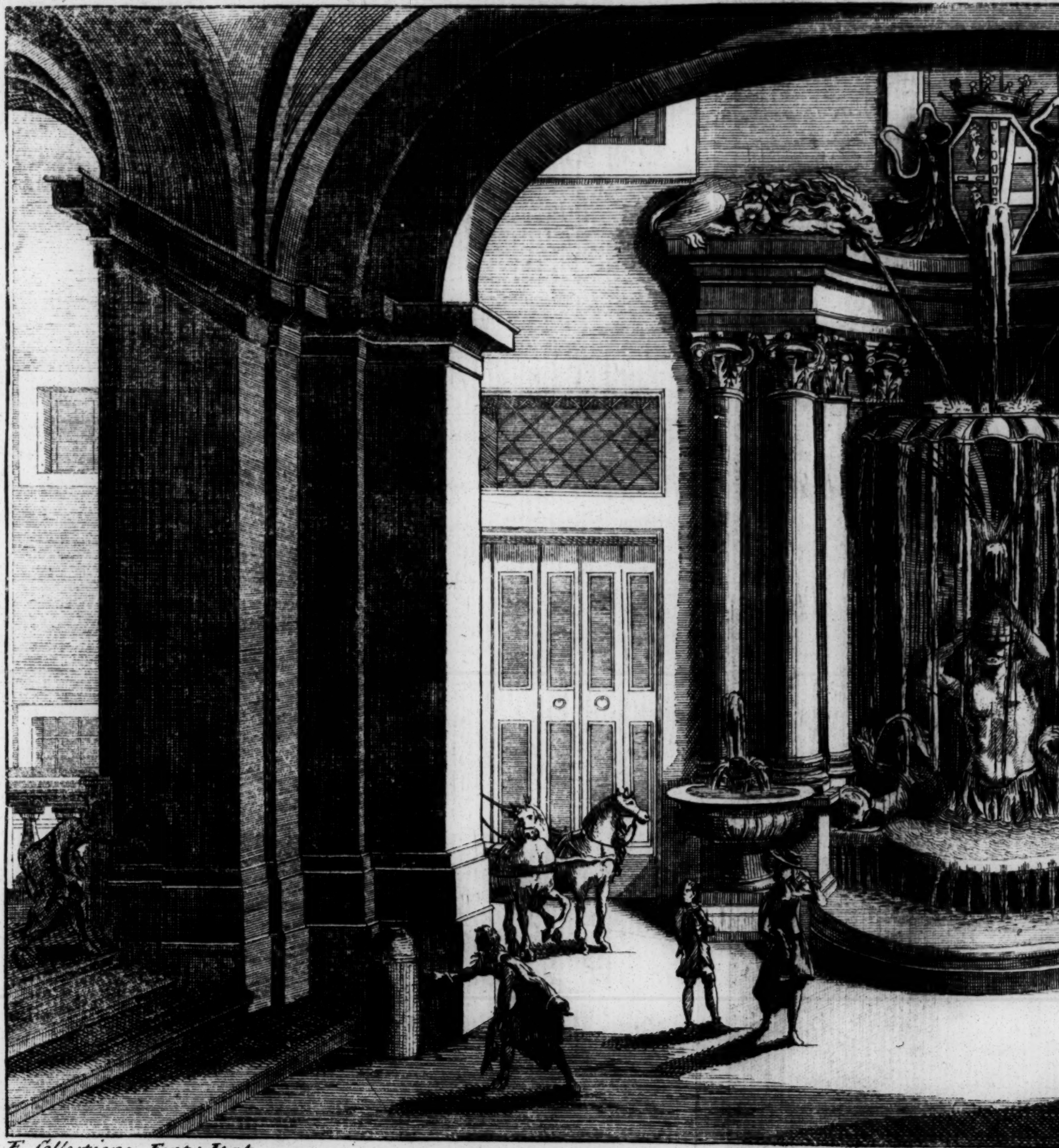


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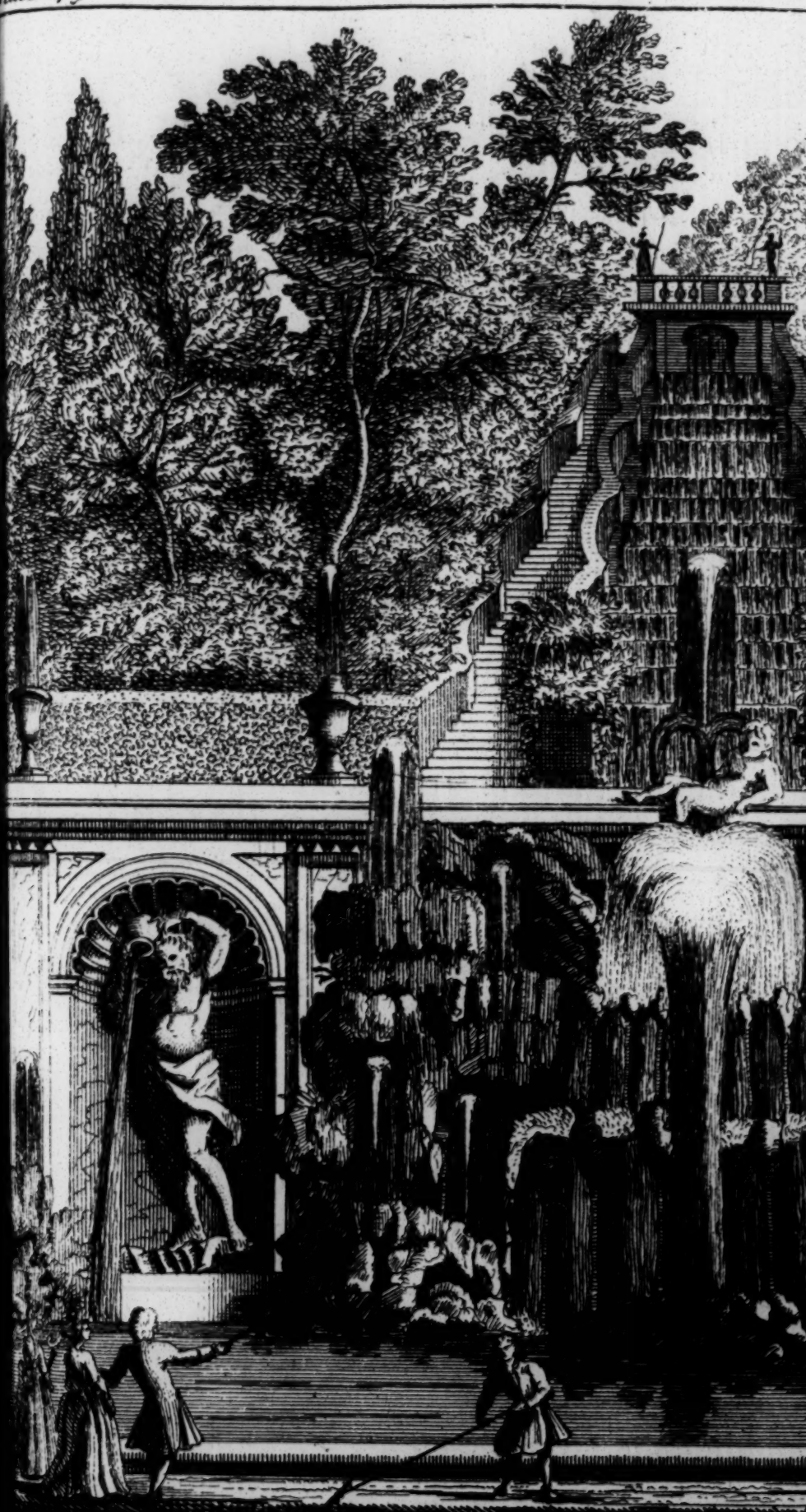


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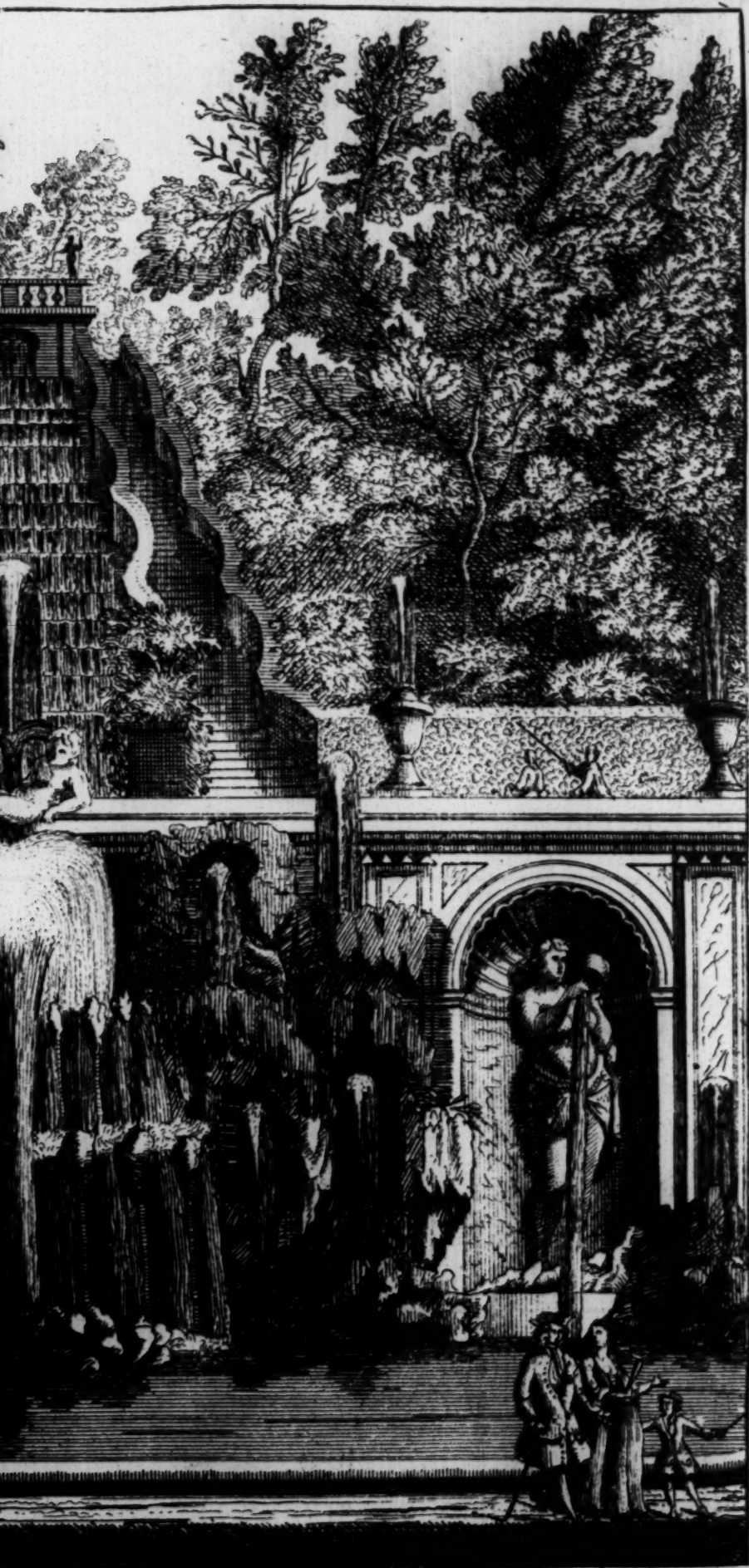
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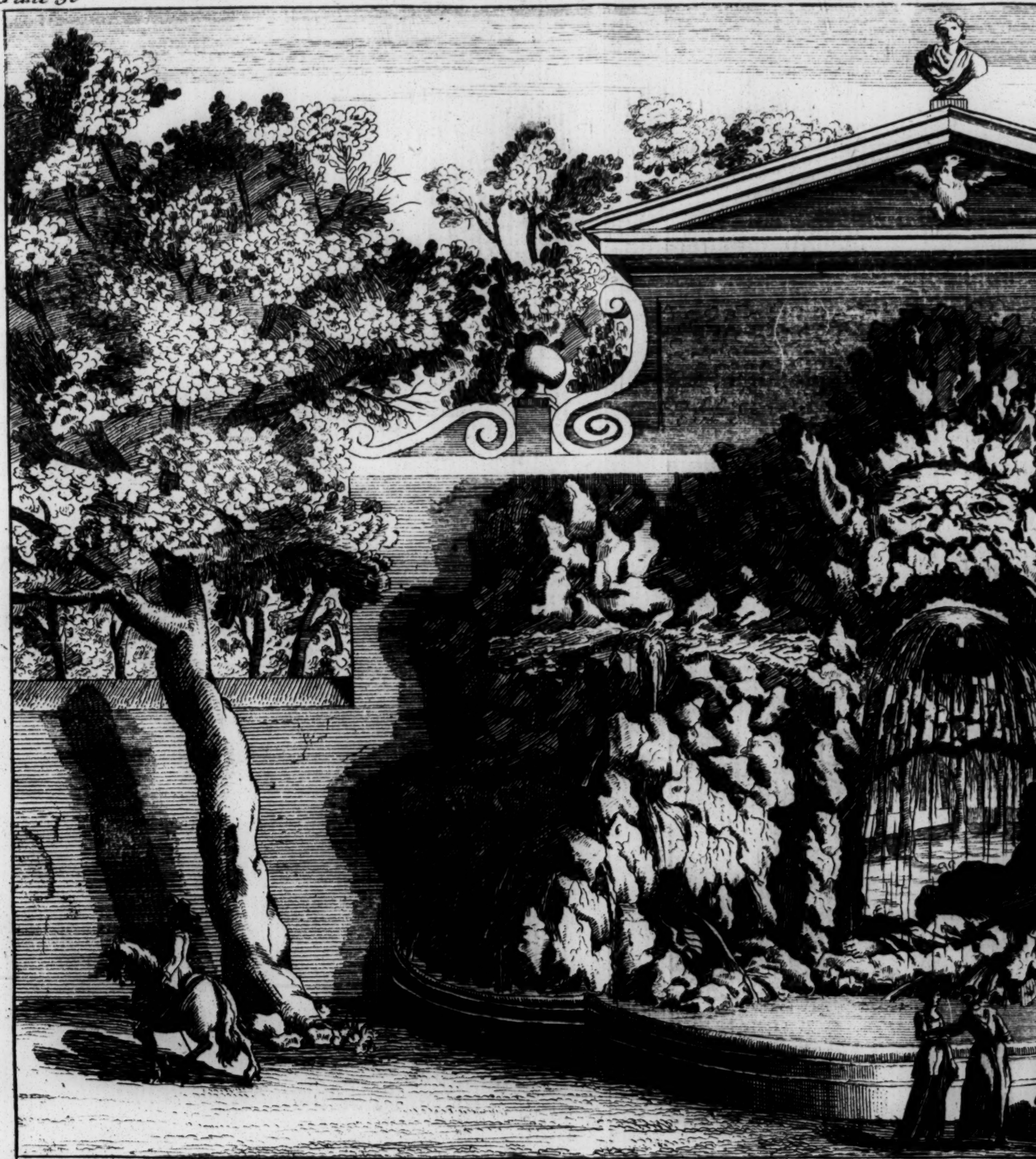
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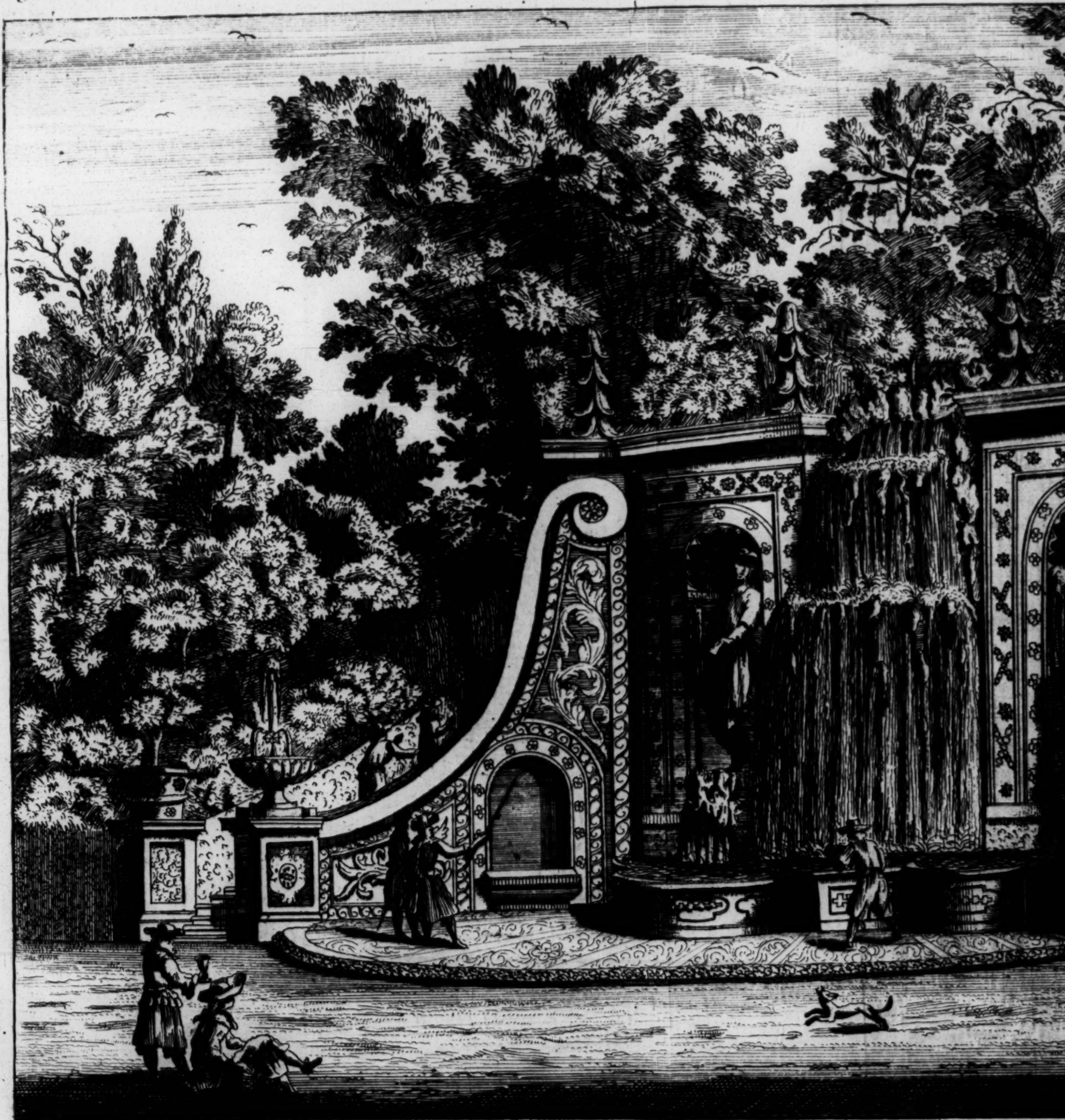
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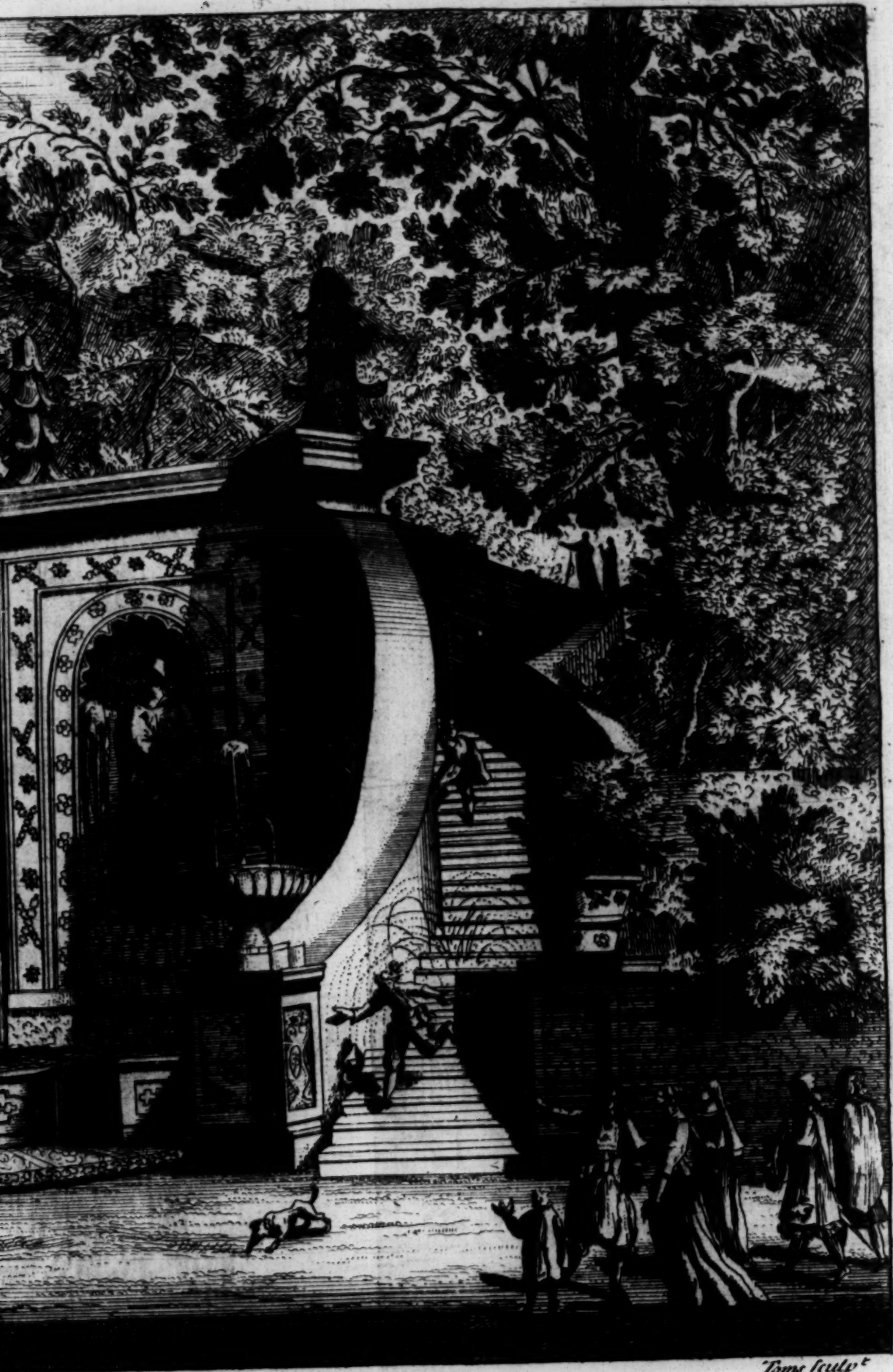


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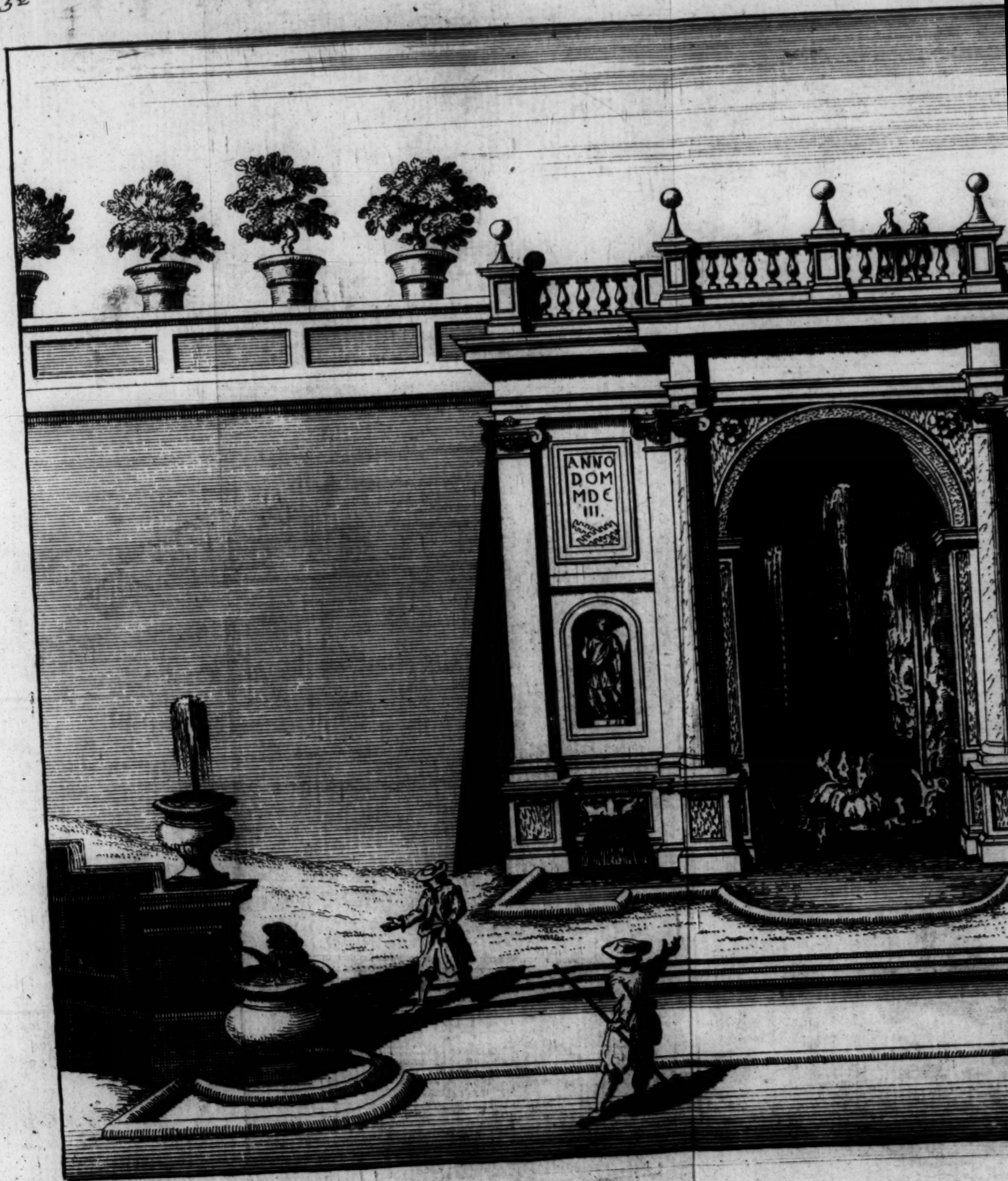


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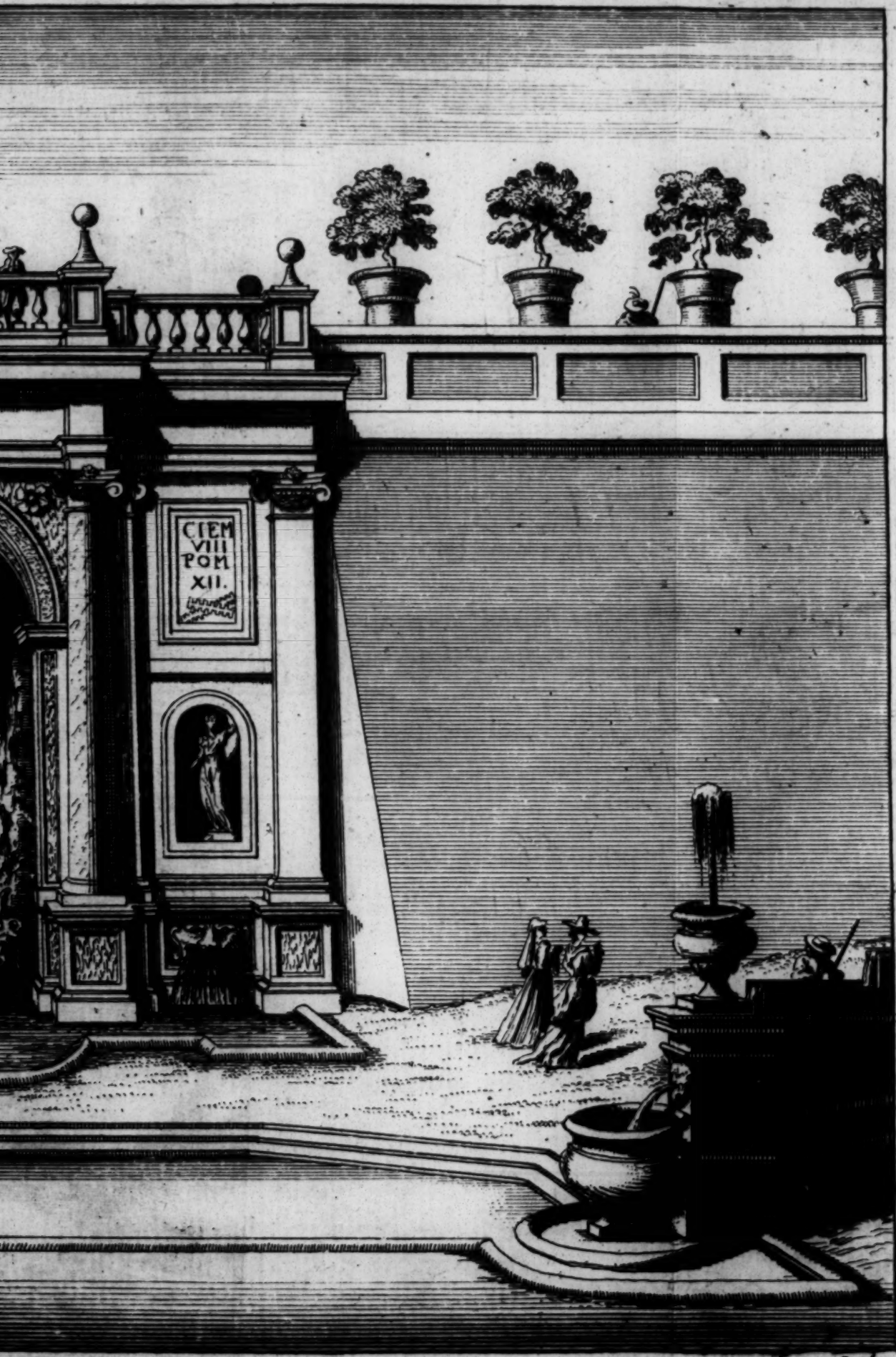


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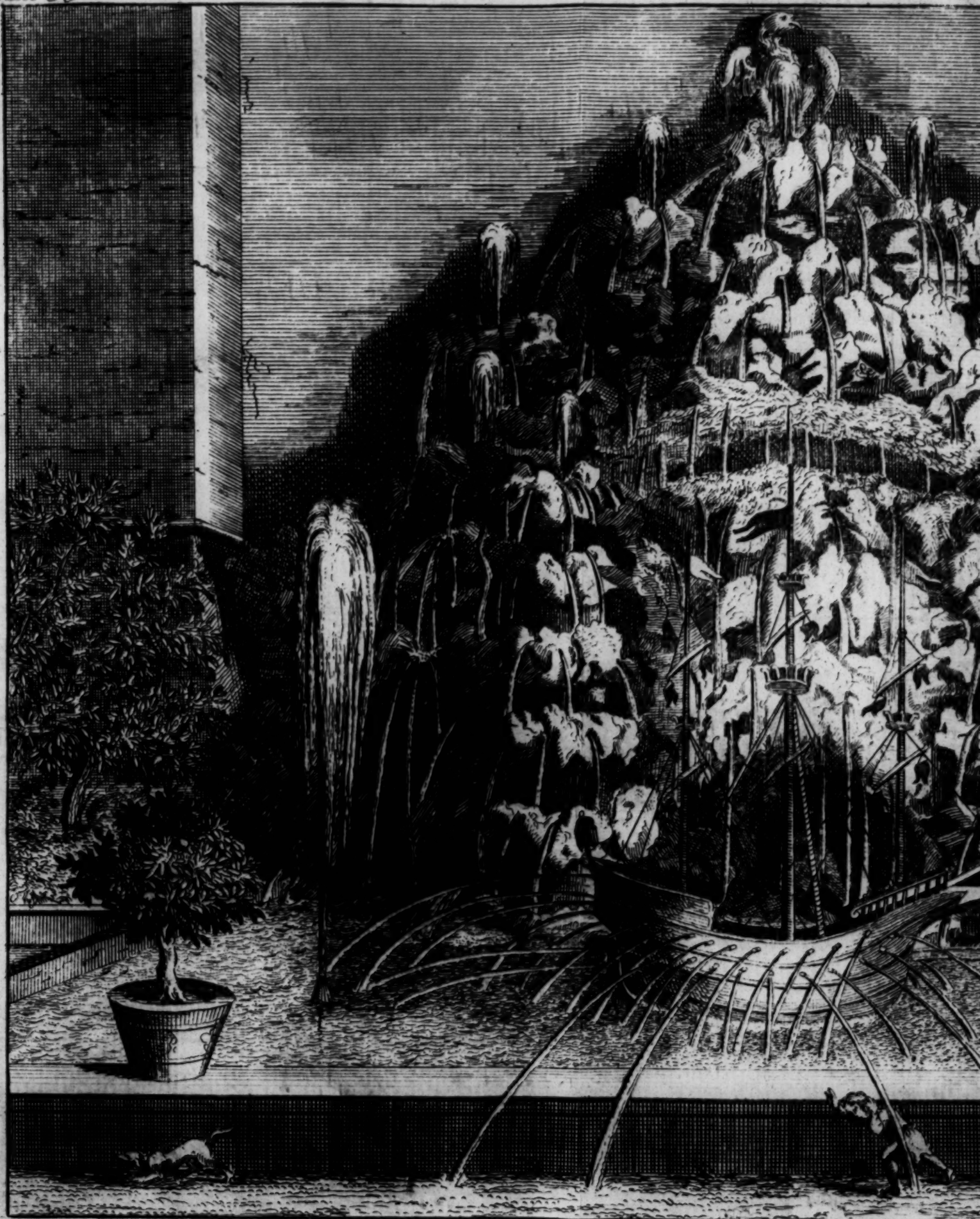


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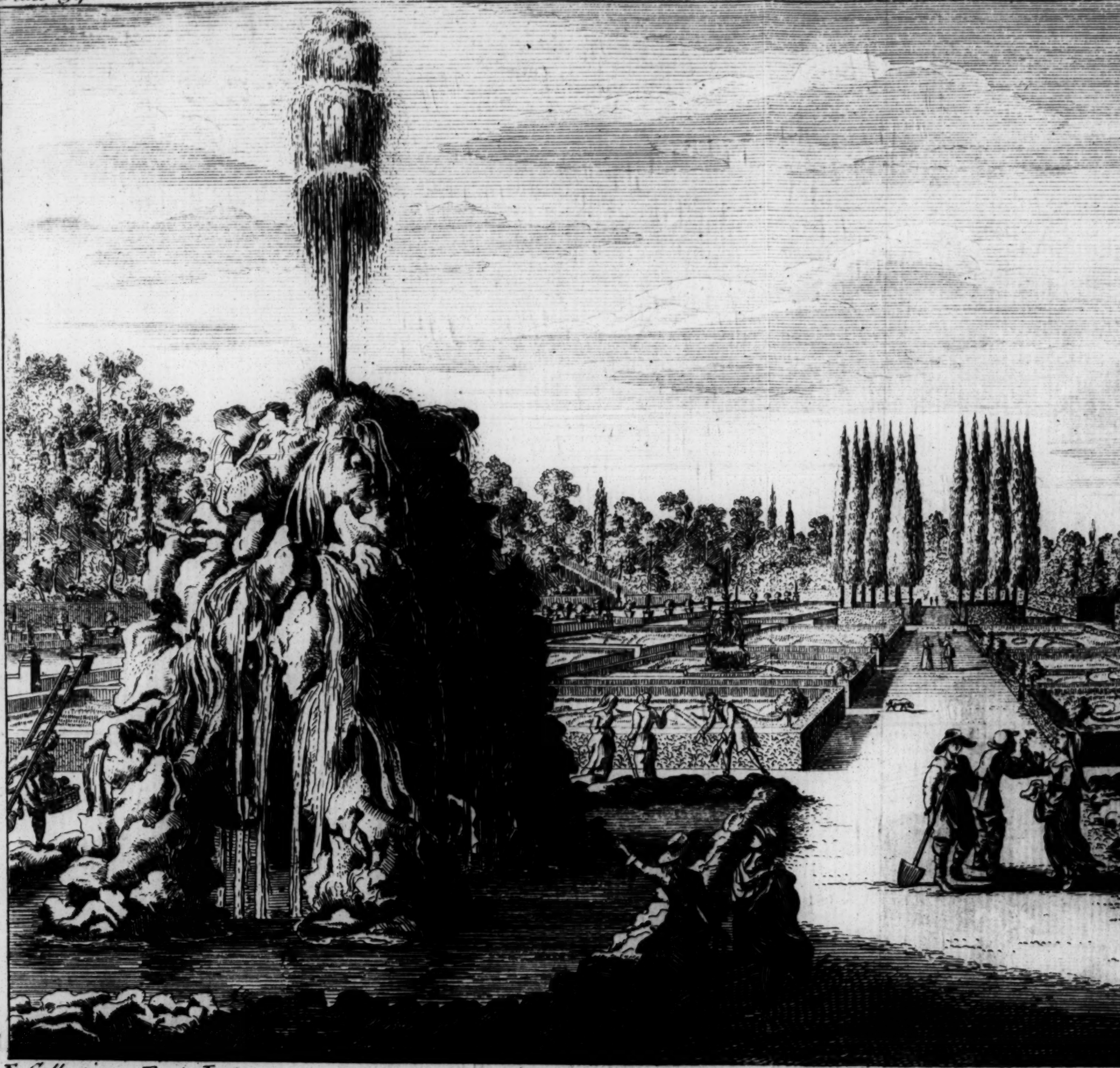


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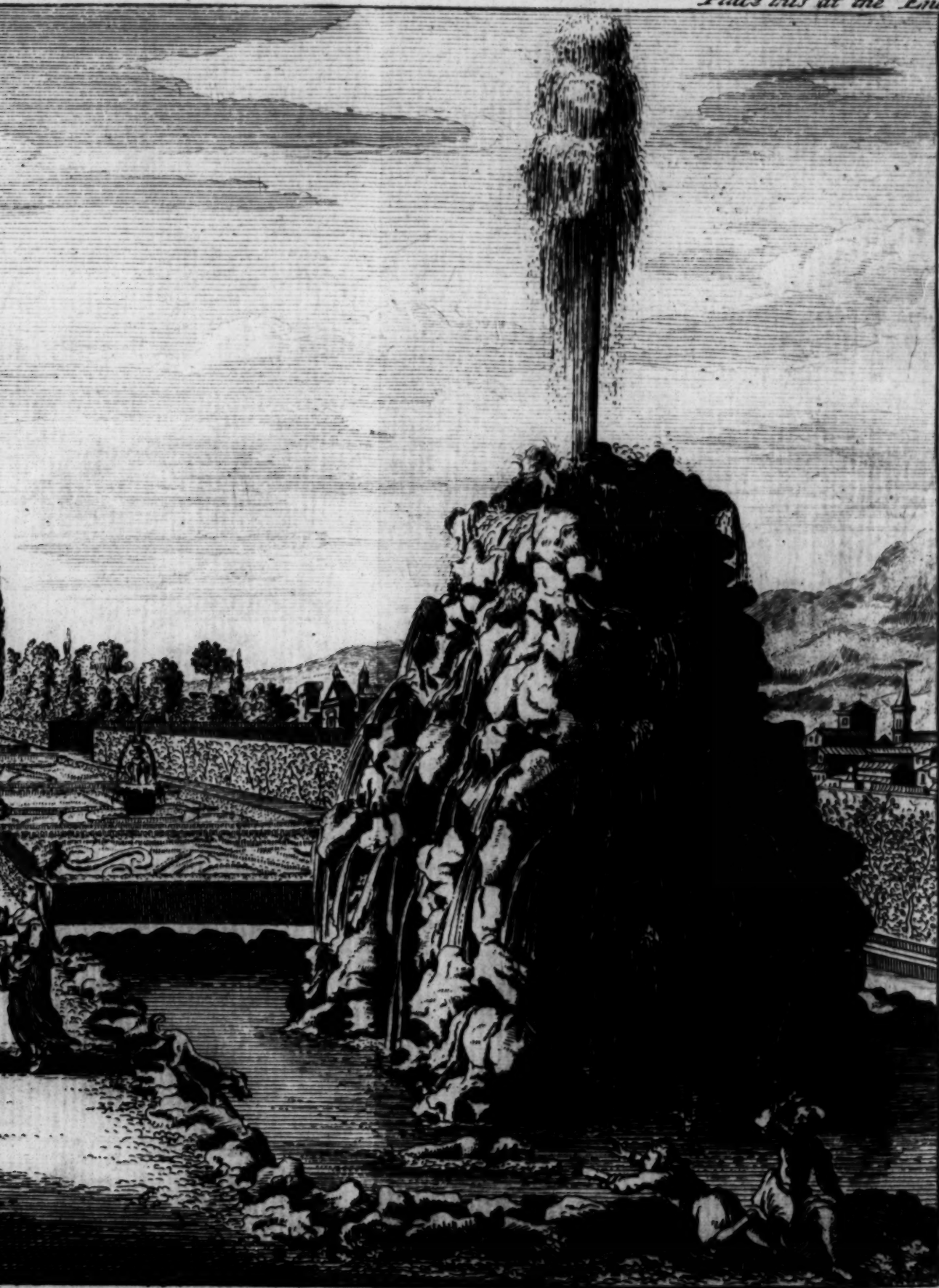
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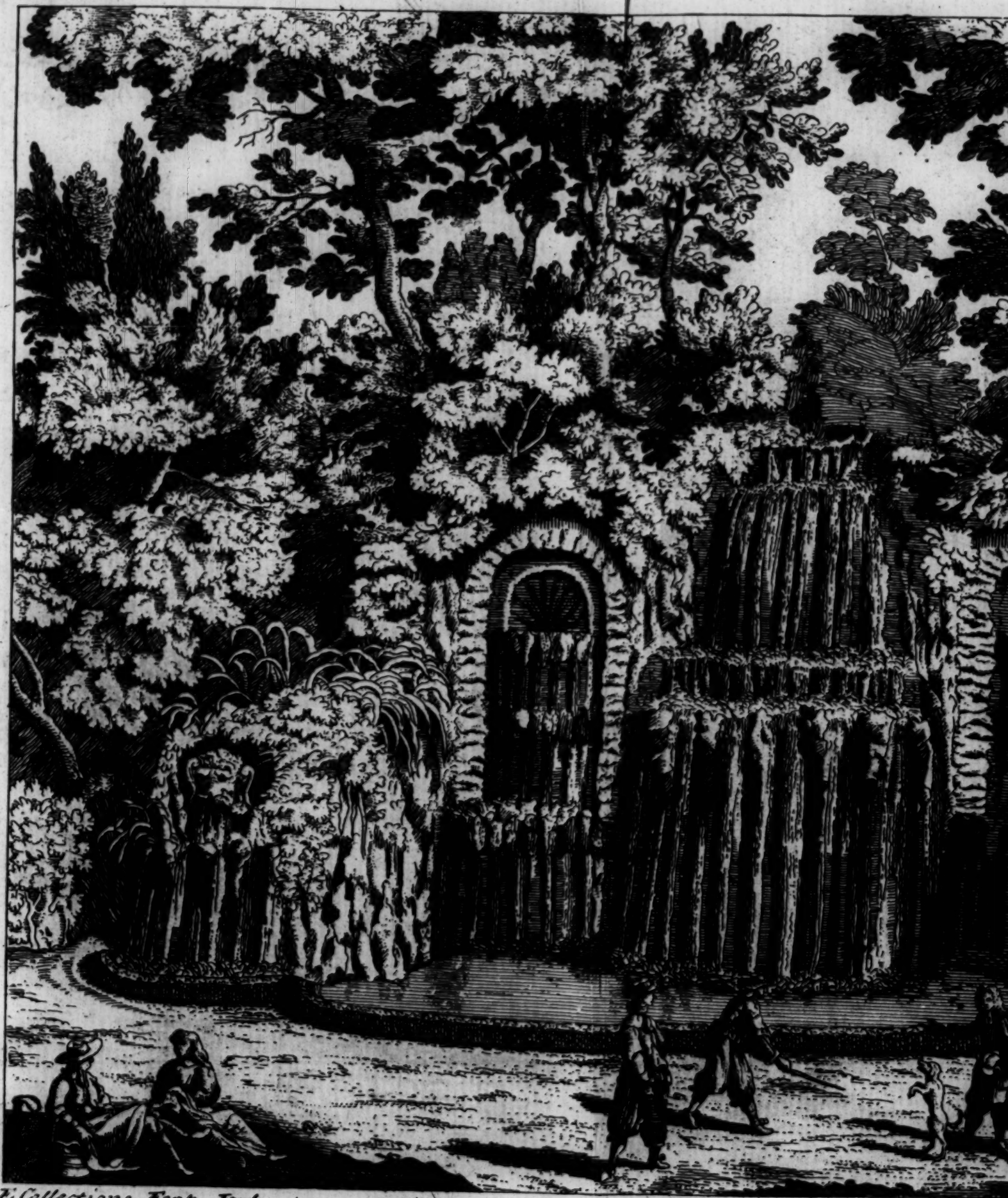
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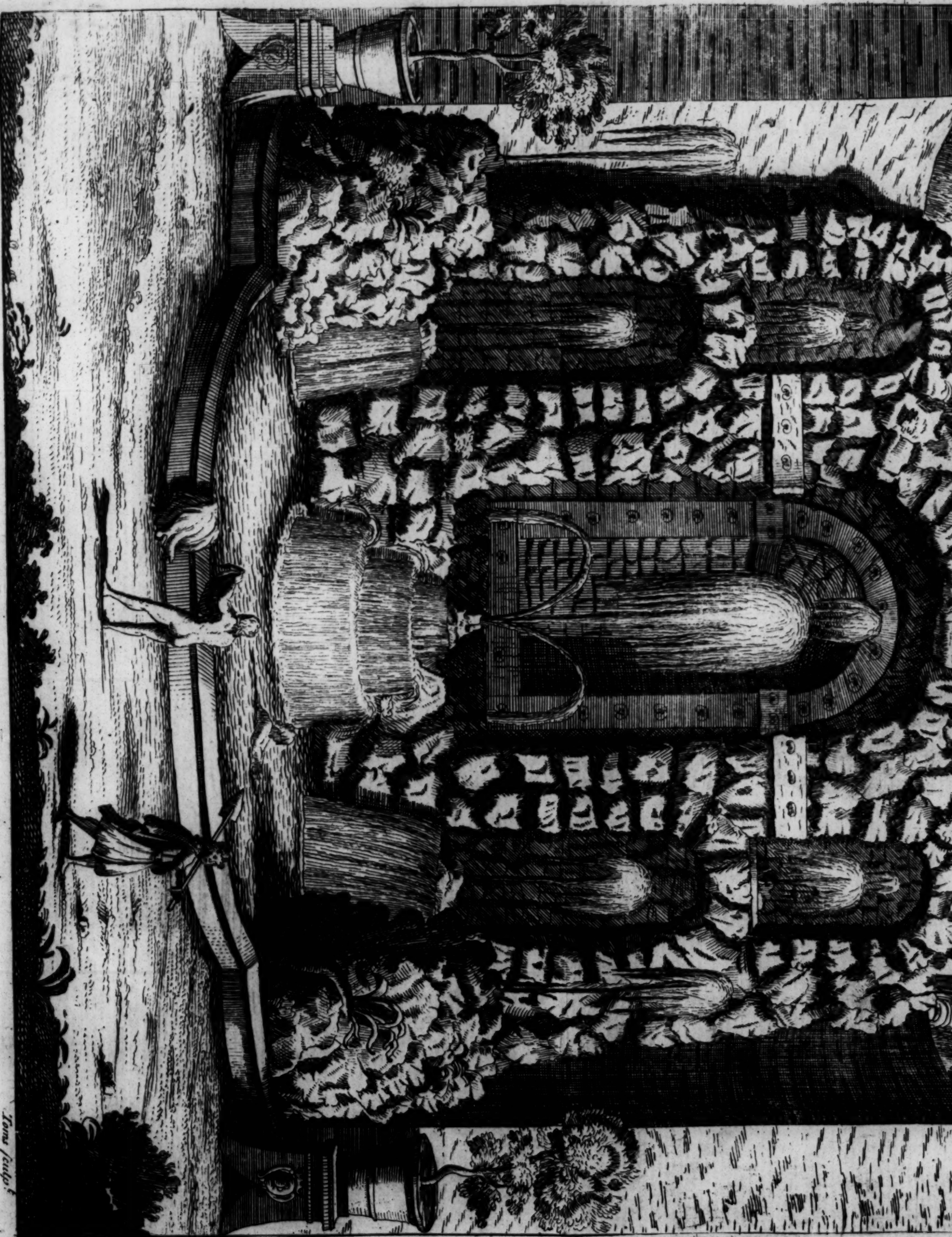
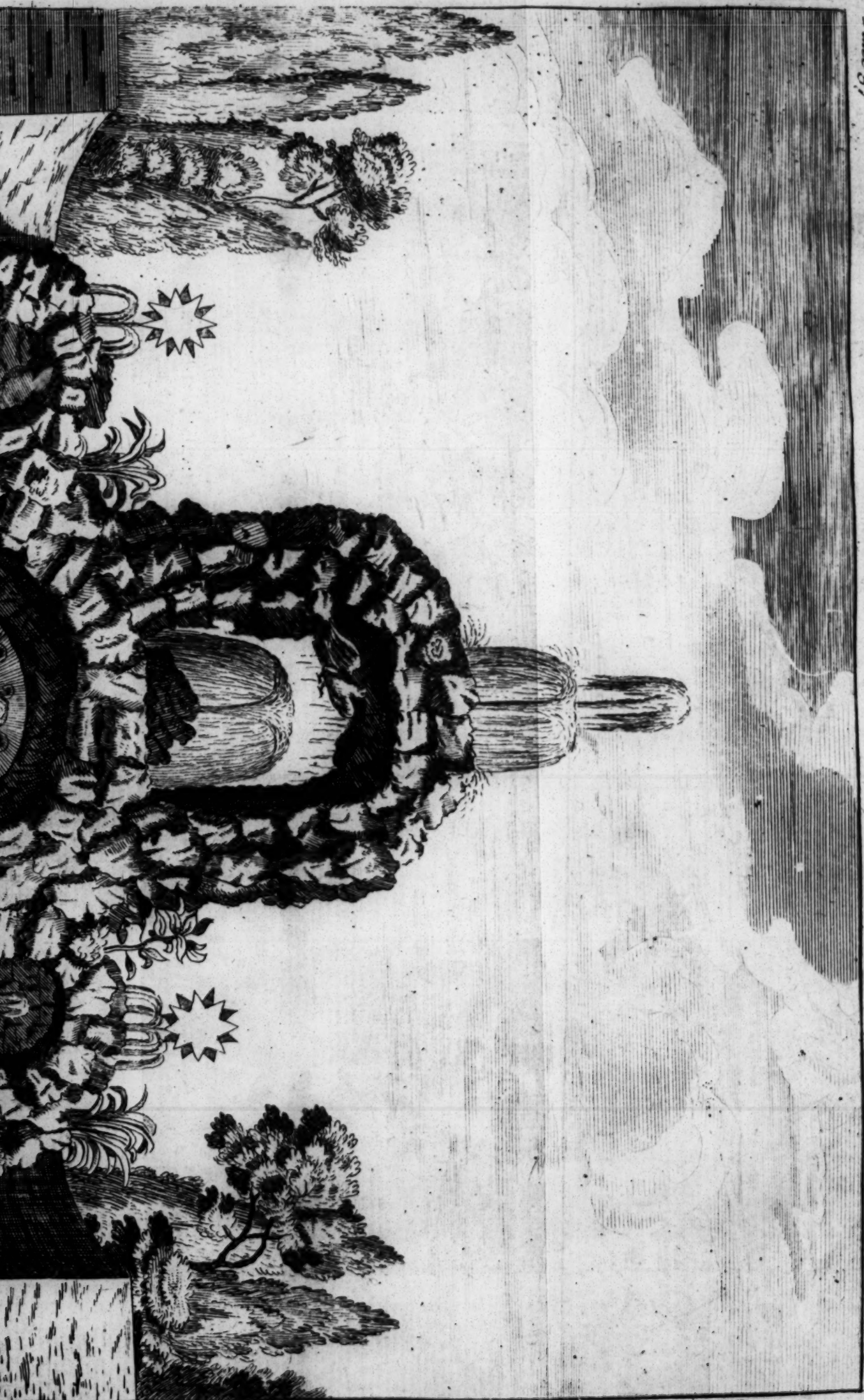
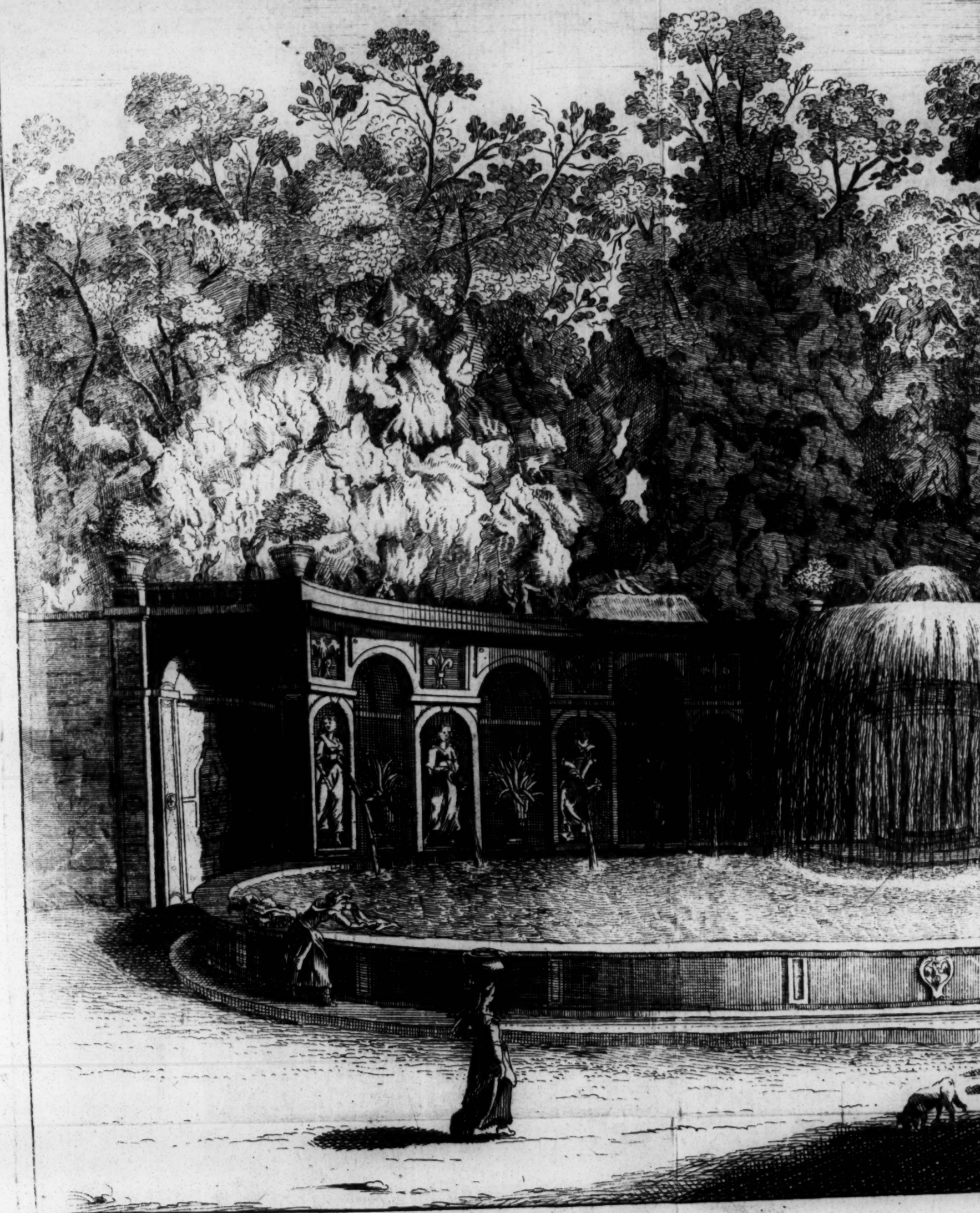


Plate 57

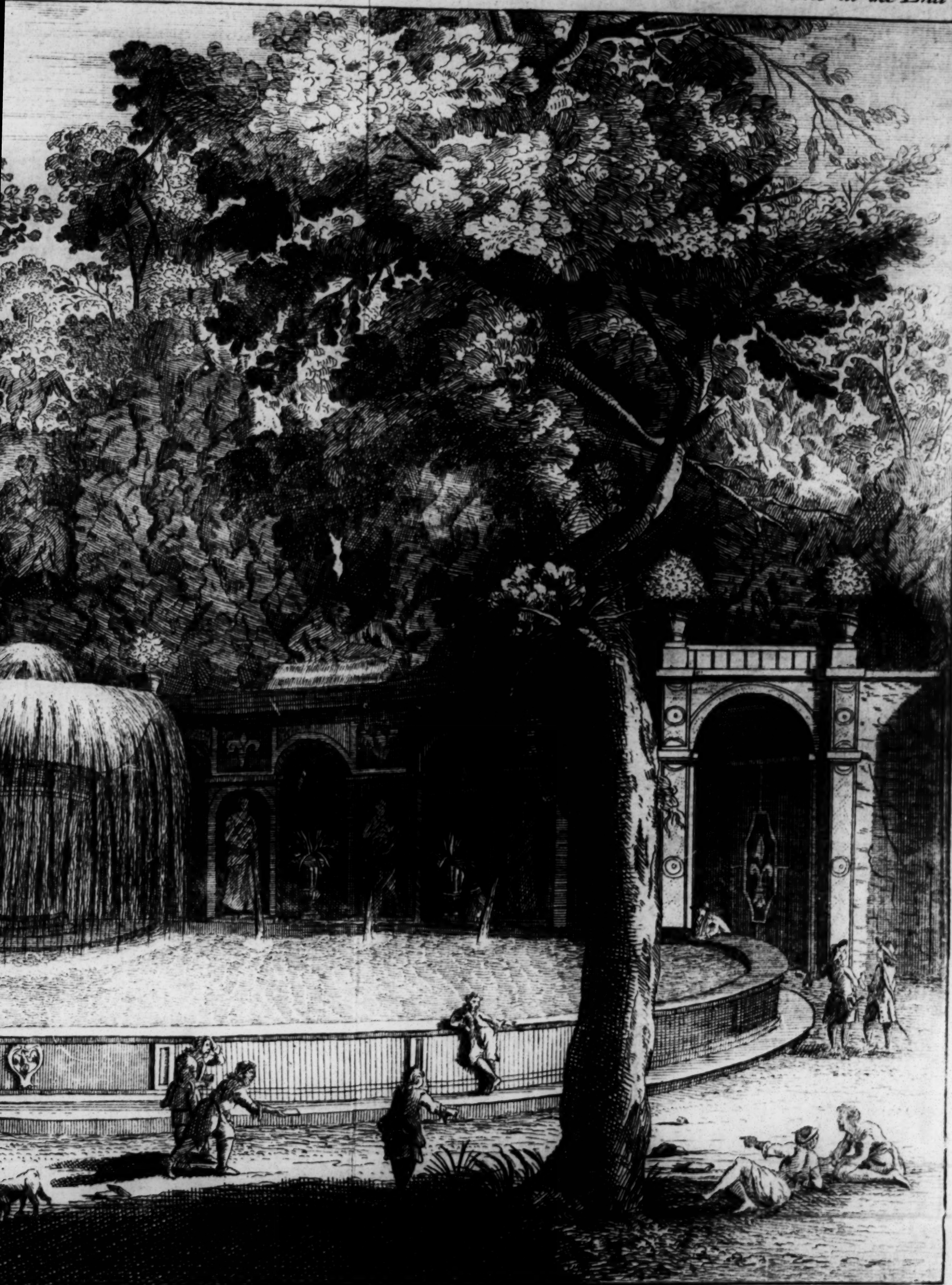


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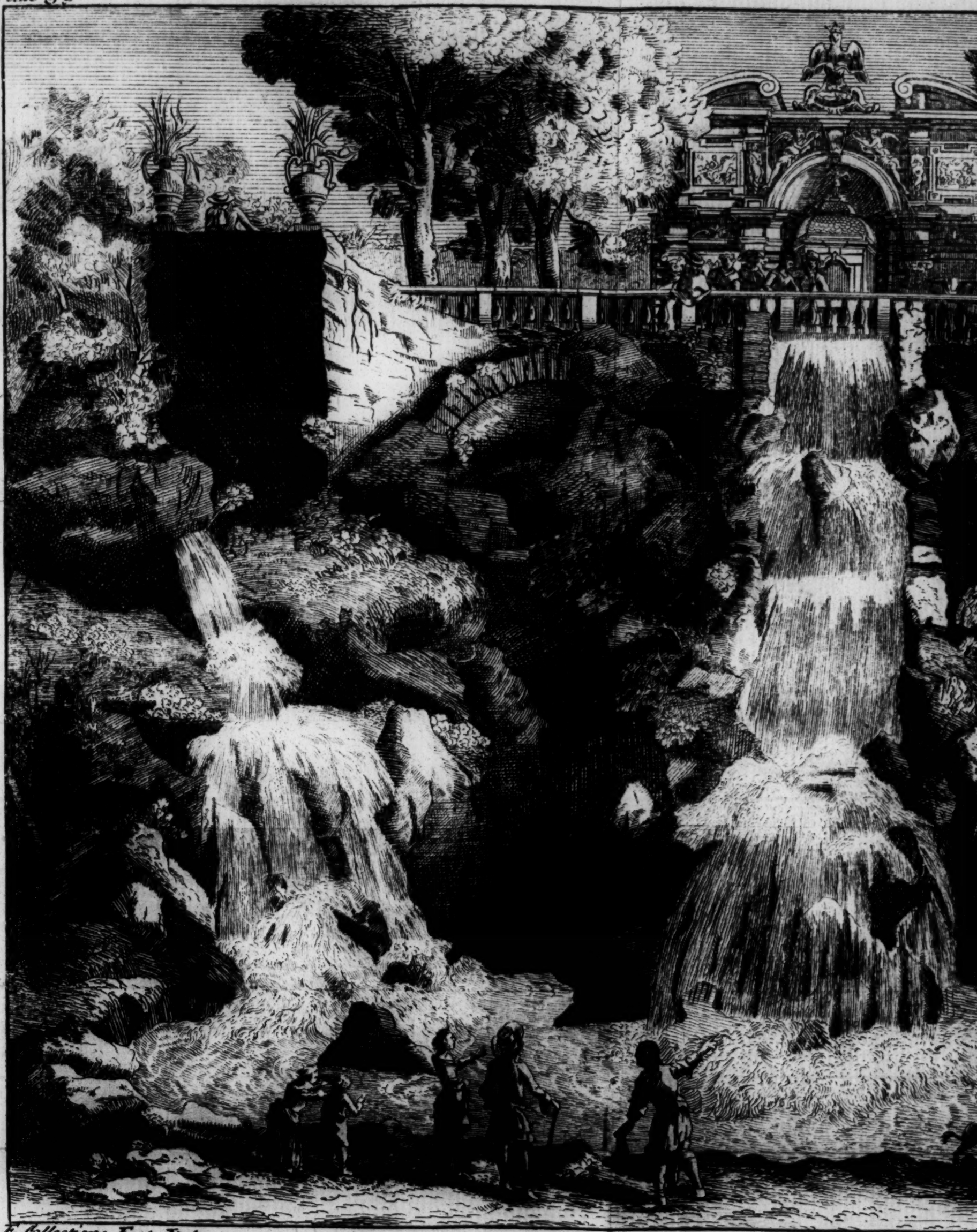


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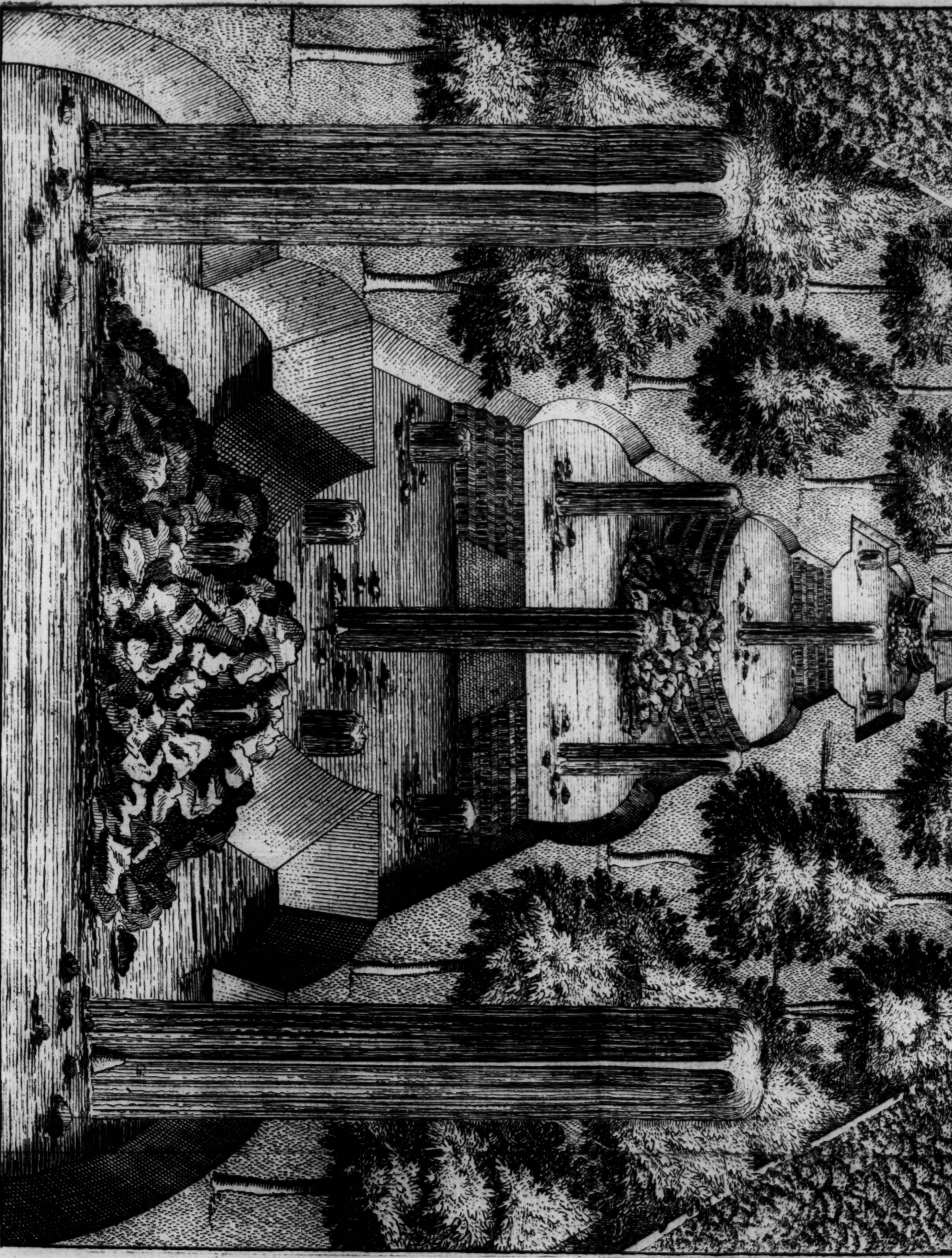
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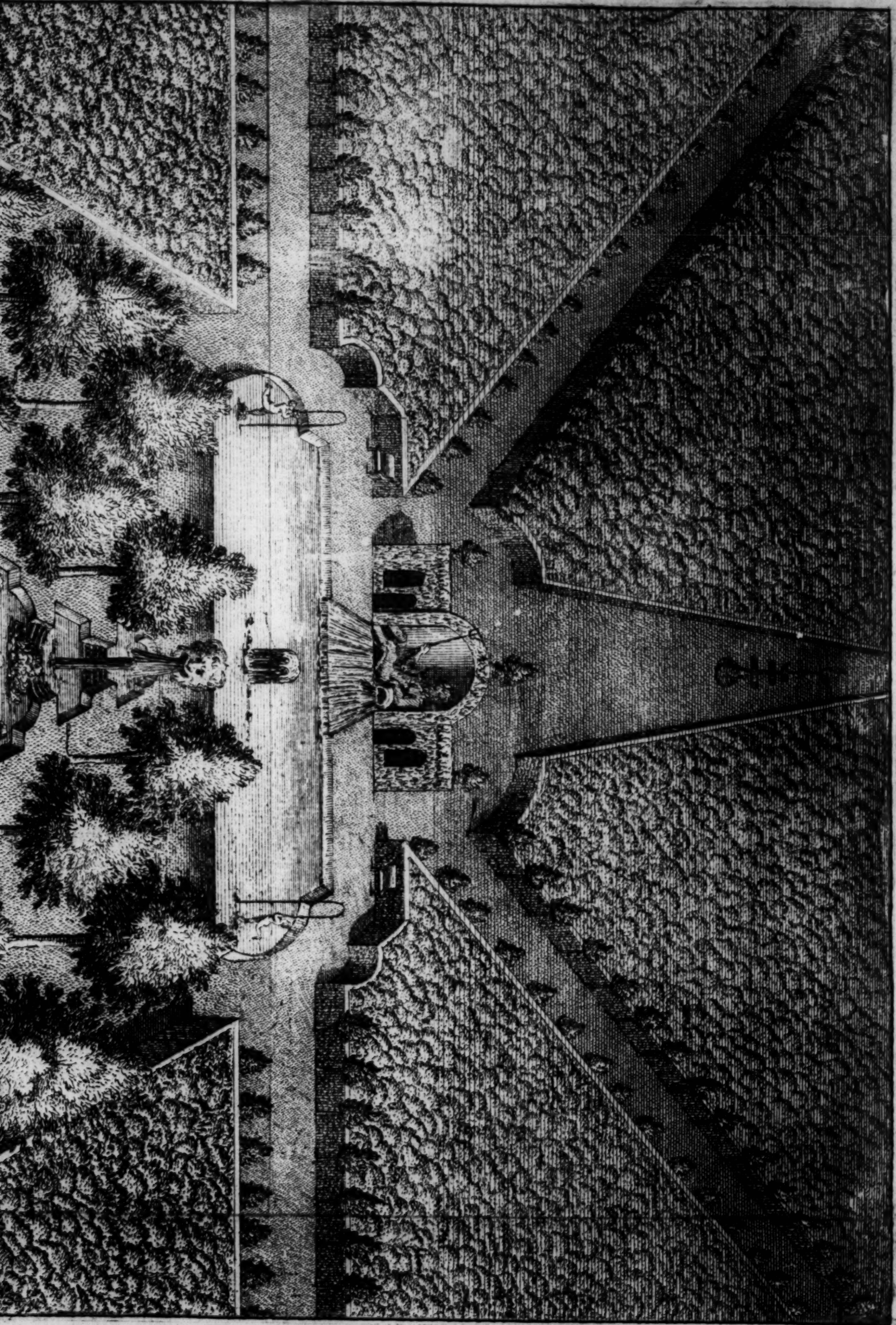


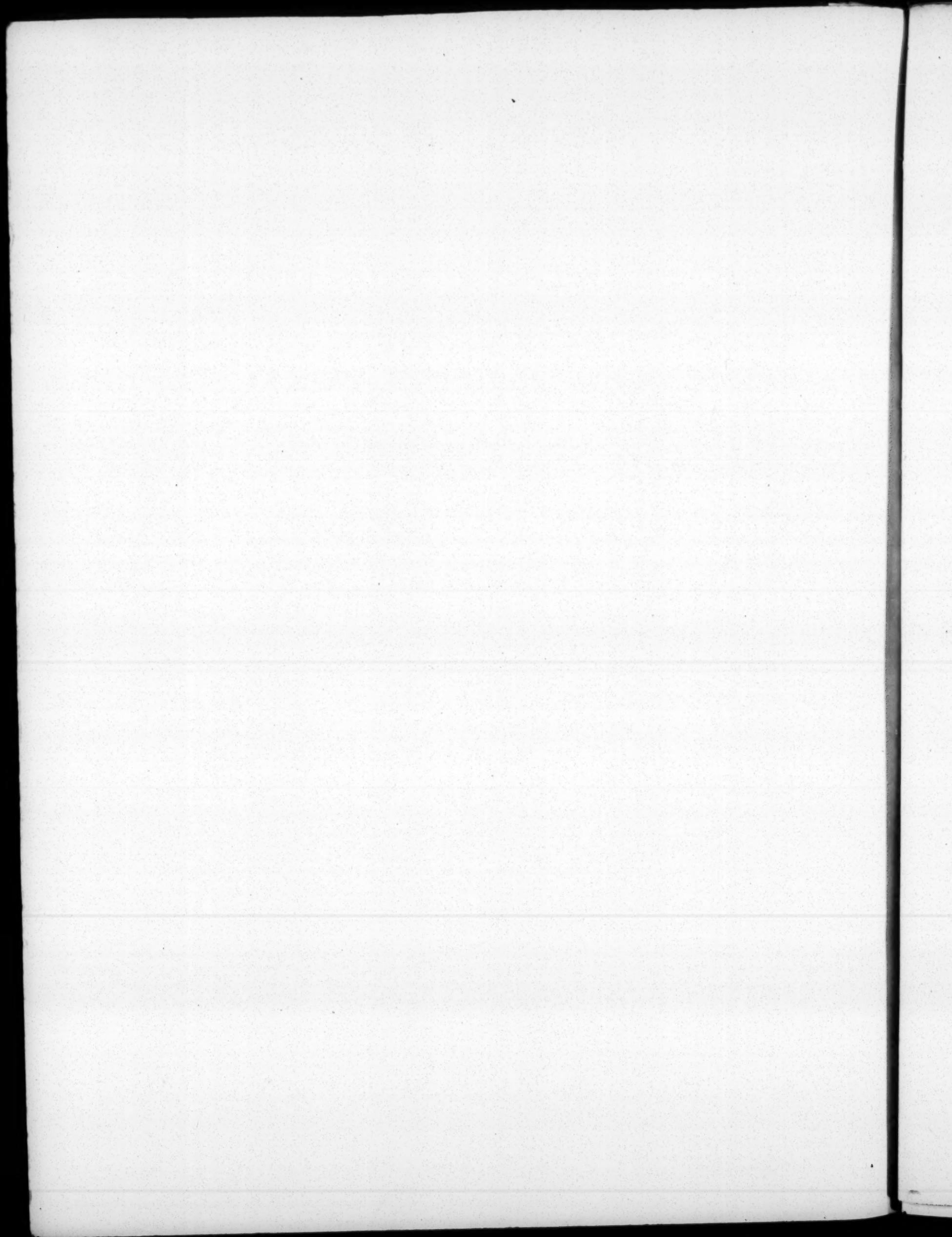
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NOTES upon BOOK IV.

CHAP. XXXV. PROP. I.

That Air may be compress'd, but not Water.



LL, or most of these Propositions, (with many others to the same Purpose,) have already been demonstrated and explained by *Wallis*, *Boyle*, and others, when we have been treating of the Gravity, Elasticity, and Impulse of the Air, and other Fluids: But their Truth is laid down by the famous *De Caus*, (with that Plainness, Freedom, and Facility,) in his short, but excellent Book of *the Theory of the Conduct of Water*, in the first seven Pages of it, that I can't but produce it as a brief Capitulation or Compendium of what all the other Authors on this Subject have in their more voluminous Works laid down.

To begin: Let there be two Vessels, A and B, of one Form, Matter, and Bigness, *Vid. Fig. 7. No 1. Plate 32.* the which let be full of Water; it is most certain, that in either of those Vessels the Water cannot be prest, so as the one of those Vessels may contain the least Part that may be more than the other: But when they are only full of Air, I say that the said Air may be prest, and one of those Vessels may contain more than the other; which shall be thus demonstrated: Let the said Vessels A and B be made very close

on all Parts, and at the Bottom of the Vessel B, let there be a small Hole E, to which the Pipe ED is fastened, the other End thereof, D, is fastened to the upper Part of the Vessel C, the which is also made very close on every Side, and containing about a third Part of the Vessel B; and to make the Water enter therein with Force, it will be necessary to fasten the Pipe F near to the Bottom of the Vessel C, the which must be made as high as may be, that it may give so much the more Violence to the Water, which entering the small Vessel C, will make the Air that is therein, to ascend into the Vessel B, which will contain more Air than A, by the Quantity which was in C; and so the Air will be prest in the said Vessel B; which may be seen, if you make a small Hole in the said Vessel, by which the Air will come forth with Violence. But if you pierce the Vessel A, there will not be the same Effect; because in it the Air is not prest. But it is here to be observed, that although the Air may be prest, it is but only to a certain Degree, which is about a third Part: And for Proof thereof, if the Vessel C were as great as B, it were impossible that the said Vessel should be filled with Water, but that the Air will often break forth, and that because B is not capable to contain so much Air: Therefore let it be held that the Air may be prest in a close Vessel to a certain Degree. There is another Way to force the

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NOTES upon BOOK IV.

the Water with Violence into the small Vessel, by Means of a Syringe, as in Fig. 7. No 2.

Prop. II. *That Water cannot enter into a Vessel, but there must come forth as much Air, except the Water be sent in by Force.* To demonstrate this, let there be a Vessel, as A, Vid. Fig. 8, No 1. Plate 32. and let the Pipe X be fastened in the Cover thereof, so that it may near touch the Bottom of the said Vessel; and let the small Vessel D be fastened to that End of the Pipe which is without the Vessel: Then if you pour Water into the said Vessel A, until it comes to be of the Height V, which is the End of the Pipe, and then the Air being shut in the Vessel A, hinders the Water which is in D, from entering into the Vessel A. But it is to be noted in this Rule, that if the Water be forced into the Vessel A with Violence, it may be filled to a third Part, or thereabouts; and the said Violence is caused, if the Pipe X be made very long, or if you force the Water in with a Syringe, as hath been said, and as may be seen in Fig. 2. No 2.

Corol. Prop. III. *It follows, by the contrary Reason, that if a Vessel be full of Water, it cannot be emptied so that the Air shall not enter therein.* As let the Vessel or Vial D, Fig. 9. Plate 32. be proposed, which let be full of Water, and let it be reversed, so as the Mouth or Neck may touch the Water, which shall be set under it in a Vessel; it is certain, that although the Mouth of the said Vial be downwards, no Water will run out, because the Air cannot enter to supply the Place of the Water that should run out.

Prop. IV. *There can be no total Vacuity.* This is that which hath been said before, the Proof whereof, may be gathered from the foregoing Corollary, and divers other Examples, whereof here is one: If you have, Vid. Fig. 10. Plate 32. a Copper Pipe B, whereof the End C is in the Water, and let the other End D be open, to the End that the Pistle A may be put therein, which will be like to those which

are used for Pumps and Forcers of Water; and that the said End A, be well environed with Leather, to the End, that putting Water in E, it may not run through to B; then if A be raised to the Point B, the Water X, which is level with the Point C, will ascend to B, to supply so much Place as is between A and F; so the Water ascends higher than the Level, that there should be no void Place left in B.

Prop. V. *If the Air be prest in a Vessel wherein there is Water, and that you give it Passage by some Pipe, the said Water will come forth with Violence.* If the Air be prest in the Vessel X, Vid. Fig. 11. No 1. & 2. Plate 32. (let it be by Means of a Syringe, or by a Pipe, as hath been said before,) it is certain that then, when the Water hath passage, it comes with a great deal more Force than if it came forth from an open Vessel, as B.

Prop. VI. *If the Water descends with Violence into two equal Vessels, there will enter more Water into that Vessel where the Water descends from the highest Place, and the Air will be more prest therein; and there shall be the same Rate or Proportion between the Quantity of Water contained in those Vessels, as there is between the Heights from whence the Water hath descended.* Let there be two Vessels, B and C, Vid. Fig. 12. No 1. & 2. Plate 32. to which the Water descends with Violence by the Pipes M and N, the longest of which is N, from whence it follows that there enters more Water in the Vessel C, than in B; and there is the same Rate of the Water D to the Water O, as there is of the Length of the Pipe N to the Length of the Pipe M. And it also follows from hence, that in the Vessel C, where there is more Water, the Air will be more prest than in B; and the Effects thereof may be seen by the small Pipes P and X, of the which two, P casts the Water highest; because the Air is more prest in the Vessel C, than in the Vessel B. In the same Manner as before, we may proportion the Air of the two Vessels to the Heights of the Water springing

NOTES upon BOOK IV.

springing forth by the small Pipes P and X, the which ought to be equal.

Prop. VII. *All heavy Things whatsoever, weigh more in the Air than in the Water.* Although every heavy Body hath always in it self its proper Weight, yet nevertheless they are also considered diversly, according to the Place where they are placed; as it is certain that Wood weighs nothing in the Water, because it doth not descend towards the Center of the Earth, which is proper to all heavy Things; but if it be in the Air, it falls towards its Center with Weight; wherefore we may say that it weighs more in the Air than in the Water: And so we may say of all Bodies, although they are heavier than the Water; for although they fall towards their Center of Gravity in the Water, yet it is not with such Swiftneſs. It is not neceſſary to ſhew here by what Quantity the ſaid Heavineſs is more weighty in the Air, than in the Water; ſending the Curious to the Books of *Archimedes* concerning Things falling in the Water; where it is demonſtrated, that heavy Things weigh more in the Air than in the Water, by the Quantity of Water which is equal to them.

Corol. *It is here to be obſerved, that Waters are of divers Weights; and they ſay, that on the Territories of Cara in Spain, there be two Fountains, in the one of which, divers Things being put, ſink to the Bottom, which being put in the other, float at Top. They report the ſame Thing of the Lake of Sodom, and of the Fountain of Arethufa. The which Effect comes to paſs, by reaſon of the Weight of the Water: And from hence we may infer, that one and the ſame Thing weighs more in lighter Water, than in heavier Water.*

Prop. VIII. *Water weighs upon that which ſuſtaineth it, according to its Height.* I have given this Example, becauſe divers have deceived themſelves upon this Subject, who have thought to raiſe Water, not conſidering the Weight, when it comes to be raiſed very high. That which is then to be underſtood by this Propoſition, is, that the Sucker, *Vid. Fig. 13. No 1. Plate 32.*

being at the End of the Pipe M, to ſuſtain the Water which is within the ſaid Pipe, that the Water weighs upon it according as the Height thereof ſhall be in the Pipe. As let us ſuppoſe that the Water be in the Pipe as high as D, and that it weighs 20 Pounds, if we fill the ſaid Pipe to E, which is as much again, it will weigh 40 Pounds; and if we double it again, it will weigh 80 Pounds: And according to the greater or leſſer Height of the Water within the Pipe M, the Sucker C will be harder or eaſier to lift up, which is that which ought to be conſider'd, when the Water is to be raiſed very high, to the Intent to proportion the Thickneſs of the Pipes to their Height, ſo as the Water that is in them may not be too heavy for the moving Force. It is alſo to be obſerv'd, that in Ciſterns the Force of the Water ought not to be taken from the Bottoms where the Pipe is ſoldered, but from the Superficies of the Water which is in them, as may be ſeen in the Ciſterns A and B, No 2. & 3. wherein the Water that is in B hath more Force, becauſe it is higher than A, although the Pipes are of equal Thickneſſes and Lengths. But of this much has been ſaid already.

Prop. IX. *The Water naturally aſcends near to the Level of the Place from whence it did deſcend.* This Propoſition is very intelligible, and is as much as to ſay, that if there be a Spring, as B, the Water whereof enters into the Receiver C, and if there be a Pipe, as D, deſcending right down, or obliquely, the Water will aſcend therein to E, which is the Level or Height above the Veſſel C: And if the ſaid Veſſel be not full but to the Point F, the Water will not aſcend through the Pipe D, but to the Point G, the Level of the ſaid Point F; and although the Pipe coming from the Veſſel C, be not drawn ſo high, if the End of the Pipe through which the Water paſſeth be ſmall and the Pipe great, it ſhall aſcend to its Level; but according as the Ends of the Pipes through which the ſaid Water paſſeth are greater, ſo the Water is deficient in its Height. This may be ſeen in the Figure, by the ſmall Pipes X Z P.

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This Proposition has been already demonstrated by *Marriotte*, *Vid. Fig. 6. No 3.* of this 32d *Plate*, but this Demonstration of *De Caus's* being so very plain and easy, I thought I could not do better than to insert it in its proper Course:

Prop. X. *Of the Syphon or Crooked Pipe by which the Water is drawn forth.* This Pipe is in Use in divers Places, and hath been treated of by *Hero of Alexandria*. But it must not be here omitted, because it falleth several Times in Use for our Subject, and also to understand the Reason thereof. This Pipe, then, is called by several, a Syphon, and hath that End which is without the Vessel, longer than the other; and if the Air be drawn forth which is within the said Pipe, when it begins to run it will not cease till it has emptied the Vessel as high as the other End; and that which in Effect may seem strange, of the said Syphon, is, that the Water riseth higher than the Top of the Vessel by the said Pipe, the Reason whereof may be given thus: Let the Vessel be B, *Vid. Fig. 15. Plate 32.* and the Syphon CVX, and let the Top thereof be V, and the End VX longer than VC; then when the Air which is in it is drawn forth by the End M, the Water of the Vessel B enters therein to fill the Place. Now it being full, the Water contained from V to X, being more heavy than that from V to C, makes it run towards M; and as that Water cannot run out of the Pipe, unless there enter something therein to fill the Place, and the Air cannot enter the Water by any Place of the Vessel B, the Water will ascend till it comes to empty it self to the Height of C, and then the Air entering therein, the Course of the Water will cease.

Prop. XI. *Of another Kind of Syphon, and how the Air may be drawn forth by the Means of another Vessel.* There may be made divers Kinds of Syphons; but behold here one which seems to be most different, which nevertheless depends upon the same Reason with the former. Let the Vessel be B, *Vid. Fig. 16. No 1. Plate 32.* and let the Pipe DC be soldered to

the Bottom passing through it: Then let one End of the Pipe AXZ be put about it, so as the End X may be closed and soldered so as the Water may not enter but by AZ, but AZ must not touch the Bottom: Therefore the Pipe AXZ must be fastened to the Pipe D by two small Tennonns, M and N, and it must be observed, that the said Pipe AXZ ought to be made of such a Thickness that the Water contained between it and the Pipe D, may be equal to the Water which is in D; which being done, the Water may be drawn forth by D, and perform the same Effect as the former. But if either the one or the other of those Syphons contains so much Air that it cannot be drawn forth by Aspiration, there must be made a Vessel, as P, very close, and soldered on all Parts, and it should have one End F to join with D, which Vessel, fill with Water, and join F and D together, without taking Air; then if you turn the Cock R, *Vid. Fig. 16. No 3.* the Water that runs forth from the Vessel P, will draw the Air of the Syphon, and make it run.

Prop. XII. *The Water runs equally by the Means of a Syphon, if the End by which the Water of the said Syphon ascends, doth only touch the Superficies of the Water of the Vessel.* Because that in the foregoing Pipes the Water runs not equally, being slower at the End than at the Beginning, it shall be shewn, in this Example, how it may run equally, that is, if to the End A of the Pipe AC, *Vid. Fig. 12. No 1. Plate 32.* a small Vessel of any Matter be put, let it be what it will, so that it may float upon the Water, and the End A of the Pipe AC be put through the same, so as the End may touch the Superficies of the Water, it is certain, that the End C will run equally; which is not so in other Syphons, which run always swifter at the Beginning than at the End.

It will not in this Place, I humbly suppose, be improper to take Notice of an Enquiry that I have often heard made by some ingenious Gentlemen, which is, Why Water will not always rise and run by the Gravitation of the Atmosphere, so as that it may be transported from
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one Valley to another, as some Books of Engineering, and the general Notion of the Atmosphere gravitating on every Thing below it, would make one believe.

In Answer to this, and to explain what I am about to deliver on this Head, it must be observ'd, that Air is of so insinuating a Quality, that it will find its Way into, and destroy the Action or Gravitation of the Atmosphere, by an Equilibrium, that for want of a repeated Suction in the ascending Pipe or Pipes, it would otherwise indeed be in a continued Motion, and would with great Ease and Certainty convey the Water from one Valley to another.

To come to Example, (*Vid. Fig. 18. Plate 32.*) let A be the Valley from which the Water is to be transported through the highest Part of the Syphon B, and to run out at D into the opposite Valley. If (say these ingenious Enquirers) it should be true that the Atmosphere will raise Water 33 or 34 Feet, the Height of the Hill E, by B, into the Valley D, or lower, why if once exhausted of the impeding Air, and set to work, will not this Syphon perform this Operation, this Transportation of the Water in an uninterrupted Manner? To this say those that are experienc'd, that all or most Syphons, Springs, and Pumps, run always swifter at the Beginning, than at the End; for Air being elastick, and so confin'd to no Regularity, will be always insinuating it self at D, and taking its Course through the Pipe by B, and more Air insinuating it self through the Mole or Mass of Earth, and crowded into all the Pores and Interstices it can meet with, impedes and destroys the Ascent of the Water, till by the Repetition of the Strokes by a Man or other Movement, plac'd somewhere about C, there is a new Suction of the intruding Air perform'd in the Pipe AC, which losing its Force by that interior Exsuction, the exterior Air gravitating, as has been before describ'd, on the Surfaces and Bowels of the Hill at or about A, rises the Water over at B, as is before describ'd.

We see even in small Syphons, as Cranes, with which Wine is decanted,

that the Insinuation of the Air is such, that Wine will not always keep on its regular Ascent, without the Butler puts his Mouth sometimes to it, to give it a new Suction; much less can it be expected that a Syphon or Crane 33 or 34 Foot high, and which is liable to be stoppt by the least Interposition of the Air, should continue its Action without a continual Exsuction and Attendance. And this we know holds good in Pumps, Syringes, &c. which otherwise would be useless Engines; but if good, are call'd, Atmosphere Pumps.

CHAP. XXXVI. *Amongst the Works of the celebrated La Bion, I find a Gauge, &c. This Gauge is describ'd Fig. 22. Plate 32. and, as Monsieur Marriotte has it, p. 190. of the English Edition, may be easily calculated the Number of Inches, which the River Seine gives: For since there passes under the Red Bridge in one Minute 200,000 Cubic Feet of Water, if we multiply 35, which is the Number of Pints which a Cube of one Foot contains, by 200,000, we shall have 7,000,000 Pints; which being divided by 14, give 500,000, which is the Number of Inches which the River Seine gives, when it is at a moderate Height.*

If we have a Mind to calculate what Quantity of Water goes through large Passages, as through a square Fathom, it is necessary to consider the Height of the Surface of the Water, above the Middle of the upper Part of this square Hole, through which the Water is supposed to run. Let it be, for Example, 5 Feet, there will be then 8 Feet from the Top of the Water to the Middle of the square Fathom. The Product of 8 by 13 is 104, whose Square Root is very near 10 and $\frac{1}{2}$, as 13 is to 10 $\frac{1}{2}$, so is 14 to 11 nearly: And because a round Inch is 16 Times greater than a round Hole of 3 Lines, an Inch with 8 Foot of Water above it, will give 16 Times 11 Pints, or 176 Pints; which being divided by 14, give 12 Inches $\frac{1}{2}$ for an Inch Diameter of the Hole. A round Hole of one Foot Diameter, gives an 144 Times more; the Product of 12 $\frac{1}{2}$ by 144, is 1810; the round or cylindric Foot then will give 1810 Inches. The round Toise contains

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contains 36 Times a Cylinder of 1 Foot: The Product of 36 by 1810, is 65160; as 11 is to 14, so is 65160 to 82930. Then a Passage of a square Fathom having 5 Feet of Water above it, will give 82930 Inches.

From thence we shall find, that if the River *Seine* were stop'd, when it is swell'd a little above its usual Greatness, and was rais'd 8 Feet above a square Hole, 10 Foot high, and 18 Foot wide, it would go all out through such a Hole: For there would be a Distance of 13 Feet from the Surface of the Water which was stop'd, to the Center of the Circle, which would have 10 Feet Diameter; and it would give through an Hole of 3 Lines Diameter, an Inch of Water: Through one of an Inch Diameter, it would give 16 Inches; thro' one of a Foot, 144 Times 16 Inches, which makes 2304 Inches: And multiplying this Number by 100, the Square of 10 Feet, which is the Breadth of the Hole, we should have 230400; and according to the Proportion of the Circle to the circumscrib'd Square, which is of 11 to 14, we should find very near 293236 square Inches; and adding to it 8 Feet in Length, we should have more than 500000 Inches; which is what the River *Seine* gives at a moderate Height, as has been said before; and consequently it would all go out through a square Hole, which should have 18 Feet in Length, and 10 Feet in Height.

If Water runs through an Aqueduct, or through the Channel of a River, in a gentle uniform Declivity, it will acquire in a moderate Space a Velocity, which will increase no more: For the Friction of the Banks, and the Bottom of the Channel, and the Parts of the Water being turn'd over one another, and the Resistance of the Air to the little Waves which are in the Surface, cause it to lose a Part of its Velocity; and consequently it cannot accelerate its Motion, but to a certain Velocity which it acquires in a little Time. From whence it follows, that if a River has run through a pretty long Space in a certain Inclination, and that it runs afterwards in a less steep Inclination, that is to

say, along a Plane less inclin'd, it will diminish its Velocity: For since it will have acquir'd in the first Inclination all the Velocity which it can have by it, and could not have been able to acquire by a less; it follows, that its Velocity will lessen by Degrees in that Inclination which is less, till it be reduc'd to that Velocity only, which it can acquire by this gentler Declivity.

Thus far *Marriotte*. And from these Rules it is, that an ingenious anonymous Author of our own Country, in his Account of Meteorology, calculates the Quantity of Water which runs through *Kingston Bridge*.

But that the measuring of Jets or Cadences of Water may be brought and apply'd to *English* Practice, it is necessary to look back on Chap. XXXIV. p. 381. towards the Bottom; where we shall find, that tho' a circular Hole of a *French* Inch, (*i. e.* $1\frac{1}{2}$ *English*), give 72 *Paris* Muids or Barrels in 24 Hours, yet as the *Paris* Muid is not equal to our *English* Hoghead, though by some considerable Authors it is suppos'd to be, the same Inch of Water will give but about 55 Hogheads and a Half in the same Time.

Again; when we calculate the Water which comes over the Head of a Cascade, or through a square Pipe or Trough, there is likewise some Difference, at least as 11 is to 14; from whence I lay it down as a general Rule, that though a circular Hole of 1 Inch Diameter give but 55 Hogheads $\frac{1}{2}$, yet a square Trough or Pipe of an Inch will give 70 Hogheads $\frac{1}{2}$, which is something more than Half a One.

Let there then be a Bay or Cascade of Water of 20 Foot wide, which is 240 Inches, and that the Water is regulated exactly to run or tumble over the said Bay or Cascade half an Inch thick, which is 120 Inches Square of Water, that Cascade will take (according to the foregoing Calculation) 11475 Hogheads to supply it a whole Day, though where Water is brought by an Engine, or the Supply of the Spring be penurious,

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penurious, the Playing of that Cascade 6 Hours, will be sufficient.

To regulate and make the Expence of Water that is to tumble over a Cascade very certain, and which is of great Use where the Water comes in a penurious Manner, the Right Honourable the Lord *Middleton*, at *Middleton* in *Warwickshire*, has made a Contrivance which I think proper to mention in this Place, because I never saw it in a Book, or elsewhere put into Practice, but there, and which will be sufficiently explain'd in *Fig. 19. Plate 32.* to this Chapter annex'd.

A represents the Canal from whence the Water comes, B the Head or Bay, made of Stone, and CCCC the Steps over which the Water falls: Now in the Head B there are seen 4 Holes, of what Diameter you please, into which Plugs are to be put, to keep the Cascade from running at all when the Water is scarce, or you have not a Mind to play it.

At the Bottom of the Head B there are Pipes which go under it, and communicating with the Canal A, are ready to spout up their Water when those Plugs are taken away, but yet so as that it will not raise it higher than its own Level at A, but yet it will come out very quick, and the Cascade will abound with a greater or lesser Quantity of Water in Proportion to the Number of Pipes you open, or the Plugs you take away; sometimes, perhaps, the Water will be plenty enough to let you open one, sometimes two, sometimes three, and sometimes all four of the Holes.

I should before have noted, that the Water of the Canal A, is kept up to a constant Gage, by a thin Stone Work, or Valve of Wood at *aaaa*. Now at *Hampton Court*, and other Places, that Barricado is a Valve of thick Board, which is made to turn down when the Water plays; but then all the whole Water which is in the Canal, must of Necessity run off in a little Time, as low as the Bottom of the Valve; and if there be not a fresh Supply behind, its Action must soon cease; where-
23. in this Invention you can let on either

more or less Water, as you see Occasion, and as your Supply will best allow. A murmuring or dropping of Water over such a Head, is amusing enough, but $\frac{1}{4}$ of an Inch Thickness is generally sufficient, and $\frac{1}{2}$ an Inch thick of Water, the most that need be allowed to any, even the largest Cascades: For I have observ'd, especially where your Water is foul, that the Thickness of your Water rowling over a Cascade, is rather a Blemish, than a Beauty to it. Note, The Head of the Cascade ought to be at least 6 or 8 Foot thick, and made battering inwards, for every Foot high it ought to be at least a Foot thick at Bottom, to discharge the great Weight which must necessarily be laid against it.

Note ult. *A farther Account of the Distribution of Water from Pipes of Conduct, into smaller Pipes, for the Supply of Towns and Gardens, by Jets, &c.* The Diameter, Thickness, and Proportion, of Pipes of Conduct, Adjutages, &c. having been fully handled in p. 126. of this Treatise, there will be little or no Occasion for me either to capitulate or enlarge upon it in this Place. But the particular Method of distributing of Water for the Supply of Cities and Towns, and divers Parts of a Garden, with some particular Directions for keeping Pipes of Conduct, and Adjutages, clean, and from stopping up, and for the helping, if not the entire Prevention of that Friction and Interposition of Air which is the too natural Consequence of all Pipes that Water comes through, yet remains as necessary to be enlarg'd upon.

To know how to manage this Distribution well, let AB, *Fig. 21.* be the Height of a Vessel which is to serve for a Gauge, and CD the Height of the Water, you must place the square Holes about two Lines below the Surface CD, in an horizontal right Line EN. Now if this Gauge be divided into several Squares of an Inch every Way, as EFPH, &c. they will give more than an Inch; for if the circular Holes give 14 Pints in a Minute, the square ones will give a Quantity that will be to 14, as 14 to 11; which Pro-
portion

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portion of 14 to 11, is pretty near that of a Square to a Circle of the same Diameter: If then a round Inch gives 14 Pints in a Minute, a square Inch will give almost 18 Pints; for 11 is to 14, as 14 to $17\frac{2}{11}$; therefore you must divide EF into 14 equal Parts; and if ER contain 11 of those Parts, the long Square ERS^H will be very near equal to a circular Inch, and it will give an Inch, that is to say, 14 Pints in a Minute, if the Water in the Gauge Vessel continues at the Height CD. You may make several Holes regularly following each other, equal to ERS^H, under the same Line EN, as RLTS, LMUT, &c. and if you would give Half an Inch, you must divide one of these long Squares, as OQIG, by a middle Line XY, and each Half will give Half an Inch, that is to say, 7 Pints in a Minute, and all the other Divisions the same, if you take the Third, as IKZQ, or the Fourth, &c. There will be this further Advantage, that if the Water that supplies the Pipes diminishes, and passing through them, fills only a Third, or the Half, or two Thirds of the Height of the Holes in the Gauge, every Person will lose in Proportion, which cannot be when the Holes are round; and if there be a little more Friction in the little Holes than in the great ones, the Water supplying the Expence through a narrow Passage better than a wide one, will compensate that Defect. If you would give 3 or 4 Inches, you must take 3 or 4 entire Holes, each equal to ERS^H, as LTUM; but you must make a little Separation, and have some Distance betwixt the Holes, when you give but an Inch to each Person; for their Waters would be confounded together, if there were but 2 or 3 Lines betwixt them; the Entrance into each Pipe must be wide enough to receive the Water of each Division.

You may distribute a Spring to several Persons in a Town, in this Manner:

Suppose that the Spring gives 40 Inches of Water in the Summer, and 50 Inches in the Winter, and 55 at other Times; you must make several Reservatories, as FG

HI, Fig. 21. where the Water may discharge it self.

In the first, which must be the greatest, you must let the Water rise to a determinate Height, as AB, where there must be a Passage for the Water to run further on, and Holes for the first Distribution, as at CDE, a Foot below AB: These Holes may be wide enough, taken together, to let 20 Inches pass through, and the 25 remaining Inches will pass above AB. It is evident, that when the Water is strongest, the Elevation of the running Water will be greater above AB; and when the Water is weaker, that Elevation will be less; but not above an Inch, at most: So that when the Water that goes into the Reservatory is 50 Inches, 20 and a half of them will go through the three Holes, and only about 19 and a half will pass through them when the Water gives but 40 Inches. We will do the same in Respect of the Water that passes above AB and that that passes through the Holes; and make little Reservatories in other Parts of the Town, where we may distribute to particular Persons the 25 Inches, and the 20 Inches; always observing to make the Holes 12 Inches, or at least 10 Inches below AB. At last, it will happen, that during the great Plenty of Water, there will remain 5 or 6 Inches of Water, which may be given to the Publick, in some unfrequented Place, for particular Uses; and this Water will remain only during the great Plenty of Water; which may be observ'd also in the other Conduits, as CDE: For there will be always some Remainder for the Service of the Town, either for Fish-Ponds, or other Receptacles for Water, that are kept a long Time without any Addition of fresh Water, and which may be supply'd from Time to Time; the rest will be equally distributed at the Rate of 45 Inches, only they will have sometimes a little less, sometimes a little more.

Frontinus, a Roman Author, has discoursed of these Conduits of Water after another Manner. What we call an Inch, he calls *Quinaria*; but his *Quinaria* was a little less: His Manner of applying what he

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he calls *Calix*, at the Bottom of which, there was a little Pipe of the Bigness of his *Quinaria*, does not seem to be just; and it would be better to conduct 10 Inches to some Part of the Town, if the Persons in that Part want only 10 Inches, and to discharge them into a long Reservatory, where such a Gauge as I have mention'd may be apply'd, that shall give an Inch, or Half an Inch, according to what is got; and when there are Persons that would have only a Line, which is the 144th Part of an Inch, or 2 Lines, which is the 72d Part of an Inch, then you must make the Gauge different from that before-mention'd. There must be made a little Reservatory apart, wherein the Water must run so as to lie always 5 Lines above the Holes; and having made a square Hole, whose Side is 4 Lines, take away $\frac{1}{4}$ of its Breadth, leaving the whole Height of 4 Lines, which will give the 9th Part of an Inch, that is, 16 Lines. Half that Breadth will give 8 Lines, and a Quarter of it 4 Lines; or else you may make the Water to lie $6\frac{1}{2}$ Lines above a Hole of a Line square, from the Breadth of which you must take $\frac{1}{4}$, to have the exact Contents of a round Line, which will exactly give $1\frac{1}{4}$ of 14 Pints in a Minute, and 144 Pints in 24 Hours, of such Pints as are the 36th Part of a Cubic Foot. If you double the Breadth, you will have 2 Lines, which will give a *Muid* or Hogthead in 24 Hours, or 12 Pints in an Hour, and 3 Pints in a Quarter of an Hour; and to be sure that such an Opening gives neither more nor less than two Lines, you must count the Time in which the Water running through it will fill a Quartern; if it does it in 75 Seconds, the Quantity expended is exact. You must let this Quantity of Water run in Pipes of an Inch Bore at least; for they might be stopp'd up in Time, if they were less; and every 10 Years Care must be taken that the Gauge-Holes do not fill with a stony Substance, which fixes to the Edges of the Holes; which, in such Case, must be made a-new.

When *Marriotte* tells us that Conduct Pipes are not large enough, a fine Mud settles in the lowest Part of them, which will subside even from the clearest Wa-

ter; and at last, as it hardens, it will wholly fill up the Pipe: Therefore it will be necessary now and then to open them at the lowest Places, so as to make the Water run out with Violence, and it will bring out this Mud along with it, provided it be not yet petrify'd.

And that if a Conduct Pipe is to be carried over some rising Ground, there must be a small Pipe solder'd to it in the highest Place with a Cock to it, that is to be opened now and then, to let out the Air; which being drawn down with the Water, gathers together in the upper Part of the Pipe, and being condens'd by the Water which compresses it, comes out in Bubbles, and strikes sometimes with such Violence against the Conduct Pipe, as to crack it, if it be not strong enough to resist; or breaks Pieces out, if it be made of any brittle Substance.

But for the Prevention of this, there are some Rules laid already down in the Chapter which relates to Pipes in the Beginning of this Treatise, which is, by soldering on of hanging Valves at certain Distances, which Valve, hangs like the Lid of a Brandy Quartern, when there is no Water in the Pipes; but when the Water comes in, it will take the Sediment with it, and drive it and the Air on before, till the Pipe is scower'd and clean'd: And as soon as the Water advances on in the Pipe towards the Place where the Valve hangs, the Air (there being another Pipe solder'd on, which reaches quite up to the Top of the Ground that the Pipe is cover'd with) will by the superior Force of the Water give Place, and take its Way out, giving the Water Room (without Interruption) to pursue its Course, and the Valve is thereby kept shut till the Water retires again, and comes no more. This I owe to Mr. *Edwards*.

To go on: *Marriotte*, as to the Distribution of Water; which is partly instrumental, and partly numerical; which if any Learner would reduce to *English* Measures, he must have Recourse to the Beginning of this Fourth Book, p. 360, 361. where the *English* and *French* Measures are stated and compared one with another.

H h

But

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But for the better Calculation of the Distribution of Water to several Fountains or Houses which will often want to be supply'd at one and the same Time, the following Method, which is entirely numerical, will (with humble Submission to those who like a mathematical Demonstration better) be much shorter and easier.

Suppose then, that there is a Reservoir which is to play several Fountains, or supply several Houses at one and the same Time, the Pipes of which are to be of different Dimensions, according to the Largeness of the Fountains or Houses the Reservoir is to supply: And let there be six Branches to go from the Main, of the following Dimensions; one of 1 Inch Diameter, one of $1\frac{1}{2}$, one of 2, one of $2\frac{1}{2}$, one of 3, and one of $3\frac{1}{2}$, or of any Dimensions.

In the first Place, you are to find out the superficial Content of the Bores of all these Pipes added together, which being multiplied as before directed,

The Content of Pipe No 1 is

2
3
4
5
6

Inch.
1
2
4
6
9
12

Which added together, is 34

Now to find out the Dimensions of a Pipe of Conduct which is to supply all these Pipes at one Time, you are to take the nearest Square of 34 Foot, either by Rules set down for that Purpose, or by the Table, which is to be found p. 377. of this 4th Book; where it will be seen, that the nearest Square in whole Numbers is 25 Inches: But then there is the Square of 9 Inches more to find out, which is 108 Parts, the Square whereof is easily found out to be 10 Parts. See the Proof.

5 Inches by 5 Inches, is
5 Inches by 10 Parts, is
5 Inches by 10 Parts, is
10 Parts by 10 Parts, is

In. Pts.

5 10
5 10

25
4 2
4 2
8 4

34 00 4

By which it appears, that the Diameter of such a Pipe of Conduct is to be 5 Inches 10 Parts: But if it is 6 Inches, or 6 to 4, the better, upon Account of the Sediment, which is apt to happen in all Pipes; which, together with the impervious Air, Friction, &c. will (as has been before prov'd) very much impede or hinder the Spouting of the Water.

I might in this Place have added much more as to the Shape or Form of the Pipes at the Place where the Adjutage or Spout is join'd to them, and of the different Sorts of Figures which the last are made of, to make the Water appear above in various Figures, of all which *Bokler* has produc'd a Number of Varieties; but as all these Gimcracks are now in a great Measure out of Use, and there being no particular Shapes made use of, the Water rising only in Columns or Mountains, out of single large Adjutages, or out of an Adjutage which has one large Hole in the Middle, and several small Perforations or Holes, such as is seen *Fig. 20. Plate 32.* no more need be added till we come to the Practice of Water-Works in the several beautiful Plates that come from *Italy* and *France*, and which by and by follow.

Fig. 20. Tab. prædic. is a small Plan of the Head or End of an Adjutage, the Top whereof is made of strong Copper, of 1 Foot Diameter, the middle Jet is 2 Inches, the second Row 1 Inch, the third Row $\frac{1}{2}$ an Inch, the fourth or out-side Row $\frac{1}{4}$ of an Inch.



